

DIVERSITY IN THE SCUTES OF CHELONIA.

A DISSERTATION SUBMITTED TO THE BOARD OF UNIVERSITY STUDIES OF THE JOHNS
HOPKINS UNIVERSITY, IN CONFORMITY WITH THE REQUIREMENTS FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY.

BY

ROBERT E. COKER.

1906.

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ROBERT E. COKER.

WITH TEXT FIGS. A TO Q AND PLATES I TO XIV.

CONTENTS.

	PAGE
Introduction	2
Character of the Diversity	2
Some Recent Views Regarding the Phylogenetic Significance of Normal and Abnormal Scutes	5
Use of Terms	9
Part I. <i>Malaclemmys</i>	13
Section 1. Observations	20
Section 2. Review of Observations	20
Inframarginals	20
Interplastrals	21
Plastrals	22
Marginals	23
Nuchal	24
Costals	24
Neurals	28
Section 3. Adjustment of Neurals and Costals	33
Section 4. Age, Sex, Symmetry	43
Summary	43
Part II. <i>Thalasseochelys caretta</i> (L).....	46
Section 1. Introduction	46
Material	46
Conditions of Development	48
Explanation of Tables	49
Section 2. Observations on Diversity	50
Section 3. Review of Observations	61
Marginals	61
Supra-Marginals	62
Nuchal	62
Costals	62

*This paper was completed in June, 1906. While unavoidable circumstances have prevented its earlier appearance, the text has had no material alteration.

	PAGE
Neurals	63
Adjustment of Neurals and Costals	64
"Incomplete Division"	65
Part III. Significance of the Abnormalities	67
Introduction	67
External Conditions	68
Inheritance	69
Atavism	69
Summary of Part III.....	73
Note	73
Literature cited	74
Explanation of Plates	75

INTRODUCTION.

At the beginning of an inquiry regarding the diamond-back terrapin, *Malaclemmys centrata* (Latr.), undertaken in 1902, my attention was attracted by the frequent instances of striking deviation from the "normal" number and arrangement of the horny scutes of the carapace. The anomalies seemed of sufficient interest to justify a record of the facts, and accordingly were included in the notes made in connection with the economic study then in progress. Later, the study was extended in some lines, as it was seen that the anomalies might have some significance for theoretical interpretation or experimental study.

For kind permission to use in this paper such data as was obtained while employed in the economic study of the terrapin, my acknowledgment is due to Hon. George M. Bowers, United States Commissioner of Fish and Fisheries, and to Professor J. A. Holmes, State Geologist of North Carolina. My thanks are also due to the officials of the Bureau of Fisheries and to Dr. Caswell Grave, Director of the Fisheries Laboratory, for many courtesies extended to me while occupying a research table in the Laboratory.

I wish to make grateful acknowledgment of my indebtedness to Prof. W. K. Brooks, under whose guidance the study has been prosecuted.

Character of the Diversity.

At first I was particularly impressed by the comparatively great prevalence of apparent "abnormalities" in the number of horny

scutes of the carapace. Longer acquaintance with a number of individuals of this species that were kept under observation at the Fisheries Laboratory at Beaufort, North Carolina, and with the eggs, embryos, and young of the loggerhead sea-turtle *Thalassochelys caretta*, made apparent a wide diversity in many respects. Among the characters in which the turtles and eggs manifested striking individual differences, we may mention shape and size of eggs and of young, shape and size of head, shape of carapace, depth of body, color pattern, boldness, habits of feeding and of hibernating and of moulting, rate of growth, etc. It seemed that a diversity in respect of scutes and plates was no more than one would expect in view of the diversity shown in so many other respects. The aphorism that no two individuals are exactly alike would seem to apply with pre-eminent fitness to certain species of turtle.

Nevertheless, there are certain features of these "abnormalities" which the observer cannot but be impressed with, and which seem to suggest some special significance. These features are:

1. *The frequent recurrence of certain more or less regular scutes in definite positions.*

2. *The striking correspondence of recurring abnormal elements of one species to those of another, and sometimes to normal scutes of other species.* Thus—

(a) In 31 specimens of new-born green turtles* 44 different abnormalities were noted, but these were reducible to 11 types; or, to omit variations which occurred not more than twice and are possibly *coincidences*, we have 39 abnormalities of 7 types. The most anterior scute of the plastron, the normally unpaired, inter-gular, was in 6 specimens represented by a pair of scutes, and in 9 other specimens was partially divided. This scute occurs in few genera, but in the normal conditions of *Macroclommys* and of *Chelys* (Gadow, '01, p. 325), there is found in this position a pair of scutes.

(b) In 3 specimens of the same lot a rectangular scute appeared in the neural series between the normal fourth and fifth shields. An almost exactly similar scute occurs twice as the only abnormality of dorsal scutes noted in 4 specimens of *Thalassochelys* (*Colpochelys*)

*See author's previous paper, '05a, p. 23.

kempii Garman; it is noted in several specimens of *T. caretta*, and in other species; and a practically identical scute is figured by Boulenger for the remote species *Chelodina novæ-guinææ* Boulenger (Boulenger, '89, Pl. 5), but the author does not state whether or not the presence of this scute is normal. There seems some ground for the belief that such a definite recurrence of a scute of fairly regular shape and position has some special significance.

(c) In 3 of the above 31 turtles, the nuchal was represented by a pair of scutes. The same abnormality occurred in 10 of 243 specimens of *Malaclemmys* (Tables I-IV) and in 9 others the nuchal, though unpaired, was marked by a median longitudinal groove. This shield occurs in paired condition in several specimens of *Thalassochelys*. In some species, notably in *Chrysemys guttatus*, the nuchal often shows a distinct notch in the anterior margin.

(d) In most genera of land and fresh-water turtles, *axillary* and *inguinal* scutes are found anterior and posterior, respectively, to the bridge and just beneath the marginals (Fig. B). These scutes are regarded as the remnants of an ancestral series of *inframarginals* separating the pectoral, abdominal, and femoral scutes of the plastron from the marginals. *Malaclemmys centrata* has "normally" only the axillary, yet over 21 per cent, of 244 specimens examined, possess inguinals, of varying size, on one or both sides.

A number of other cases might be mentioned of recurring scutes in definite positions in the neural, costal, and marginal series, but these instances are sufficient to illustrate the nature of the conditions that have led some recent writers to assume that these abnormal scutes are *atavisms* and that, as such, they have a comparative value, similar to that of normal scutes, but of much more significance, since they may point more directly to remote ancestral forms.

Finally, it must be said that many other scutes are noted which are not of these definite types, but which are perhaps not less significant.

In the present paper I will present my observations on the scutes of two species of turtles, and then, in the light of these and other observations, will inquire into the basis for an atavistic interpretation. It is necessary first to have in mind the phylogenetic sig-

nificance attached to normal scutes. Some representative views are given in the next section.

Some Recent Views regarding the Phylogenetic Significance of Normal and Abnormal Scutes.

O. P. Hay's view as to the origin of the carapace (Hay, '98) is quite important in this connection, for he seems to have been the first to realize the probable phylogenetic significance of the epidermal scutes. Previous discussions had centered chiefly about the dermal and periosteal bony skeleton.

Hay distinguishes three kinds of bone in the carapace: (1) cartilage bone; (2) true dermal bone, developed in the skin itself, and comparable to the osteodermal plates of *Dermochelys* and of the crocodiles; (3) fascia bone, originating subcutaneously by ossification of the fascia below the skin. The present carapace owes its phylogenetic origin to the complete fusion of cartilage and fascia bone. True dermal bone has probably completely or almost completely disappeared from the carapace of modern Thecophora. But, according to Hay, the ancestors of all turtles, *Thecophora*, as well as *Athechæ*, have possessed an armor of true dermal bony plates, probably mosaically arranged, and with twelve well differentiated keels. Of the keels, five were dorsal (one median and two pairs lateral), two were marginal, and five ventral (one median and two pairs lateral). The plates of this armor were adapted to previously formed epidermal scutes of the same mosaic pattern. This osteodermal armor is retained in *Dermochelys* with essentially the primitive pattern, but the epidermal shields are lost in the adult and indicated only in the young.

In Thecophorous turtles the mosaic 12-keeled dermal armor underwent important modifications partly in correlation with the greater development of the internal skeleton. The plates became very much reduced in number, a few of the plates of the keels, growing in size, and assuming the whole function of the protective armor, crowded out many of the keel plates, and all of the smaller plates between the keels. Some of the keels too were lost. As the result, we may suppose a dermal carapace of twelve series of scute-covered plates, with

a comparatively small number of units in each series. This armor overlapped, or "broke joints," with the yet imperfectly developed cartilaginous carapace, but with the further development of the latter, and the consequent loss of the usefulness of the outer armor to the animal, the dermal skeleton became reduced and finally disappeared. The epidermal scutes, corresponding to these plates, remain, however, and from their present arrangement in the carapace of Thecophorous turtles we are enabled to infer something of the modifications which the dermal armor underwent. Probably the last remnants of the dermal plates persisted as small ossicles at the keel prominences that are noticeable in adults of some species, but especially in the young of certain species (e. g., of *Thalassochelys*, cf. Fig. 74). In the further course of evolution these remnants became either completely reduced or merged into the deeper plates underlying them; but Hay has observed at least one, and probably two such ossicles in the neural series of a fossil specimen of *Toxochelys*.

Thus, in Hay's view, the series of scutes of the carapace are directly homologous to the series of epidermal areas overlying the plates of the keels of a young *Dermochelys*. The neural series corresponds to the median dorsal keel. Of the two lateral dorsal keels, one is represented by the costals, while the other is lost in most turtles, but preserved as a short series of supra-marginals in *Macroclommys*. Marginal keels correspond to marginal scutes. Of the two lateral ventral keels, the internal gave rise to the plastral scutes, while the external is more or less reduced, but still survives in most turtles, either as a continuous series of inframarginals (sea turtles, etc.), or as isolated axillary and inguinal shields. In some land tortoises this series is entirely unrepresented. The median ventral is almost entirely lost, but remnants are seen, for example, in the characteristic unpaired intergular of *Chelodina*, and in the occasional occurrence in other species of small unpaired scutes in the median line of the plastron. Such a scute is most commonly found just at the apices of the gulars and is referred to as an "intergular," or, better, as an "*interplastral*."

An hypothesis advocated by Newmann follows in logical order

upon Hay's view; but a view advanced by Gadow should be referred to here, as it is not only the next in chronological sequence, but is the first in which the atavistic interpretation was applied in a comprehensive way to the abnormalities of scutes.

The two striking features of Gadow's paper are: (1) the attempt to classify the variations and interpret them as *reversions to ancestral conditions*; and (2) the hypothetical explanation of these atavisms as stages in ontogeny or *arrests of development*. In his own concise words, the abnormalities are viewed as "simply ontogenetic stages, passing reminiscences of earlier phylogenetic conditions" (Gadow, '05, p. 638).

Originally, according to this author, there was a scute for each dorsal plate. Thus, as there are eight transverse series of dorsal plates, each series consisting of a median neural and a pair of lateral costals, so there were originally at least eight transverse series of dorsal scutes, scute and plate coinciding. But a process of reduction ensued. First, by the reduction of a pair of costals (probably the second), the scutes of neural and costal series came to dovetail into one another, and this dovetailing plan was subsequently retained throughout all stages. Gradually the number of scutes was reduced by the suppression—first, of the second costals, then of a neural; then fifth costals, fifth neural, and finally by the fusion of the last two costals; thus was attained the present typical condition of *Thalassochelys* with six neurals (including the nuchal), and five pairs of costals. When turtles are found with more than this number of scutes the condition is to be regarded as "reminiscent" of one of these phylogenetic stages. The order of suppression of scutes given above is inferred from the relative frequency of recurrence of "supernumerary" scutes in the several positions. Thus far, Gadow's interpretation, though open to criticism, is interesting and suggestive. When he goes further, and regards these atavisms, when found in adults, as instances of arrested development, or, when found in younger turtles, as proper stages in ontogenetic recapitulation of the phylogenetic stages, his position seems untenable on the basis of any facts now in hand, as the writer has previously shown ('05 a), and as Newmann's observations also indicate (Newmann, '06, p. 92).

Newmann ('06), who has made the most extended study of the abnormalities of scutes and plates, lays much stress on the phylogenetic significance of scutes, but departs materially from Hay in that he regards *Dermochelys* as out of the line of descent of Thecophorous turtles, as "an abnormal and perhaps highly specialized form." This is a position which Baur held and zealously defended in a series of papers from 1886 to 1896 ('86, '88 a and b, '89 a and b, '90, '96).¹ The view was adopted by Case ('97).

Newmann bases his view primarily on a study of the assumed atavisms and of the color patterns of the carapace, but in part also on the comparison of the different scute-plans normal for different species of turtles. The keynote of his paper is expressed in the words: "Careful study has convinced me that these abnormalities are to be considered not as meaningless anomalies but as examples of systematic atavism in the sense of de Vries. From this standpoint it seems possible to throw some light on the phylogeny of *Chelonia*."

These abnormalities as Newmann regards them are reversions, not to the keel plan of *Dermochelys*-like turtles, but to a plan essentially similar to that found in the "tail-trunk" of modern *Chelydra*, where he believes the primitive condition of the scutes is most nearly preserved. There he finds seven principal rows of scutes and, alternating with them, seven subordinate rows of smaller or less regular scutes. To homologize these with the series of scutes in the carapace and plastron,—the seven principal rows correspond to neural (one), costal (two), marginal (two), and plastral (two); these rows are found in all carapaces (except those of the Trionychoidea). The seven subordinate rows correspond to (a) paired neuro-costals (lost in all turtles); (b) paired supramarginals (preserved normally only

¹Newmann's statement ('06, p. 99) that Baur with Hay regarded *Dermochelys* as the ancestral form, seems based on a preliminary note by Baur dated October 6, 1886, and appearing in the American Naturalist for January, 1887. Subsequent to the writing of this preliminary note, even prior to its appearance, Baur had discarded the old and generally accepted view, so that his complete paper, dated October 26, and appearing in the Zoologische Anzeiger for November, 1886, announced unmistakably the view which he thereafter maintained.

in *Macrochelymys*); (c) paired inframarginals (preserved in sea turtles and, as inguinals and axillaries, in most other turtles, but entirely lost in a few land tortoises); and finally, (d) unpaired interplastrals—preserved normally only as a single intergular in a few species, as *Chelodina*. In general, the principal rows are retained in all turtles, but the subordinate rows are largely lost. Remnants of these latter series, however, are retained in the normal condition of some species, and, further, *reappear as atavistic abnormalities* in individuals of species that do not normally possess them. Thus, *inframarginals* were found “abnormally” in *Graptemys geographica* and *Chrysemys marginata*, etc.; *interplastrals*, in specimens of *Chrysemys*, *Chelydra*, and *Graptemys*. Newmann does not seem to have found either *neuro-costals* or *supramarginals* as individual variations.

Furthermore, Newmann believes that the number of scutes of the neural and costal series was formerly about twice as great as at present, and that alternate scutes have been forced out and lost, but that these, again, recur in individuals as atavisms.

There has been, then, a reduction both in the number of rows and in the number of scutes in a row; but atavistic occurrences of the lost elements are met with in abnormal individuals of many species. From a systematic study of these atavisms, we may infer something of the evolutionary history of the Chelonian carapace and plastron.

Newmann differs from Hay in supposing fourteen original rows as opposed to Hay’s twelve; in seeking the ancestral type not in *Dermochelys*, but in the disposition of the scutes of the base of the tail of *Chelydra*; in supposing but a comparatively small number of original scutes in each series of the carapace; and in seeking a basis for his views in the systematic study of atavisms.

The question of the value of the anomalous scutes as evidence of phylogeny will be discussed in a later portion of this paper.

Use of Terms.

The term “scute” will apply invariably to a horny shield of the epidermal carapace; “plate” to an element of the bony carapace; “seam” refers to the line of separation of adjacent scutes, as “suture” to that of adjacent bones.

The nomenclature of the scutes will be clear from Text-figs. A, B and C.

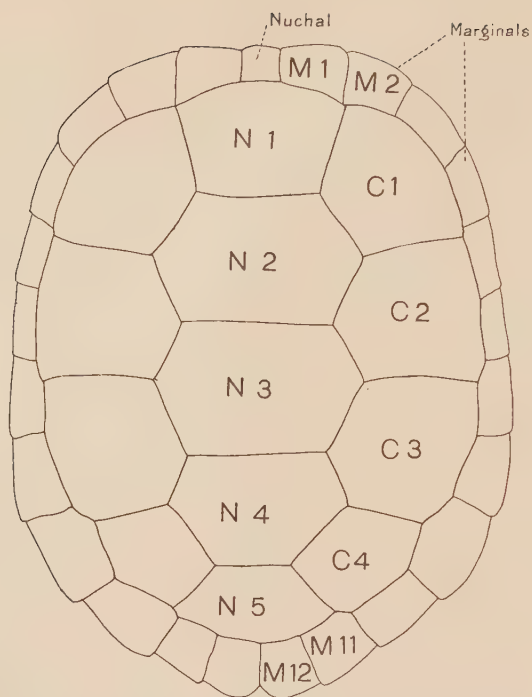


FIG. A. Normal carapace of *Malaclemmys centrata* (Latr.) (No. 253 of Table V). A median series of unpaired scutes composed of a small anterior *nuchal*, followed by 5 large *neurals*; 4 pairs of *costals*; 12 pairs of *marginals*.

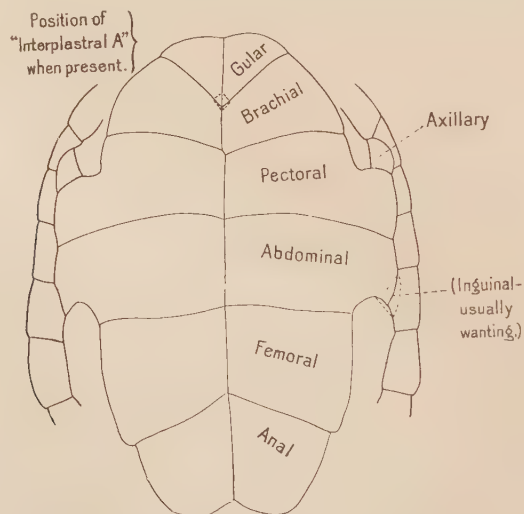


FIG. B. Normal plastron of *Malaclemmys centrata* (Latr.). Dotted lines indicate the positions of *inguinals* and *interplastrals*, normally absent.

(See also "abbreviations," below.) The *nuchal* is not, for present purposes, included in the *neural* series. As the term "intergular" is commonly applied both to the unpaired scutes, anterior to the gulars (typical of certain species) and also to a smaller or larger median scute at the posterior-median angles of the gulars (of other species), I will use the name *intergular* only in the former sense, for a median scute on the anterior margin between the gulars (Fig. C); *interplastral* is applied to other median shields of the plastron (Fig. B). The terms "inframarginal" and "submarginal" must be distinguished. *Inframarginal* applies to a series of scutes separating pectoral and abdominal shields from the marginal series (a typical series in *Cheloniidae*, etc. (Fig. C), and, presumably, represented in other species by the *axillaries* and *inguinals*) (Fig. B); *submarginal* is used, as applied by Baur ('90), to anomalous scutes found between the inframarginals and marginals (Fig. C).

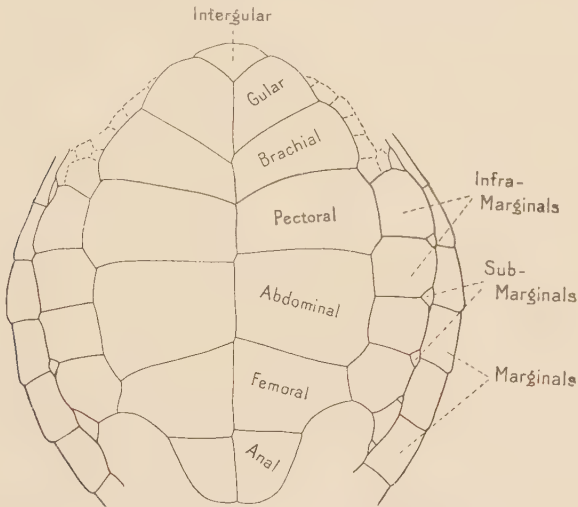


FIG. C. Plastron of a specimen of *Thalassochelys caretta* (L.). Note the anterior unpaired *intergular*, the series of *inframarginals*, and the small anomalous *submarginals*.

It seems impossible to escape the use of words that could be taken to imply more than is intended. It may, for instance, be perfectly *normal* for one turtle to have a scute not possessed by most of its fellows of the same species, but, for our present purpose, the number and arrangement typical of the species is termed "normal." A scute not found in the typical plan will be described as an "abnormality," an "anomaly," a "supernumerary" scute, or a "variation." The collective term least liable to mislead is "diversity," and this is used whenever practicable.

Explanation of Tables.

Abbreviations: "L," left; "R," right; "N," neural; "C," costal; "M," marginal. Thus "N1" denotes the first (most anterior) neural, LC4, the fourth (most posterior, typically) left costal, etc.

In the "inguinal column," "L" denotes the presence of a left inguinal, "R" of a right, "L R" of both. If the left inguinal is distinctly larger than the right, this is indicated thus "L > R," or, if the reverse is the case, "L < R."

In the "Remarks" column "Supn'y" is used for *supernumerary*.

In the "nuchal" column, "pr" indicates that the nuchal is represented by a pair of scutes, "f," that it is marked by a longitudinal furrow, not distinguishable as a seam.

The letter "x" in any column refers the reader to the "Remarks" column.

In the "figures" column, letters refer to text figures, numbers to the figures on the plates.

Regarding the identification of scutes, it is not always clear to which series in the carapace an anomalous scute should be referred, or in fact whether there is reason in ascribing it to any normal series. But for convenience of description scutes will, when possible, be referred to normal series.

In dealing with forms of so high a market value as the diamond-back terrapin (Tables I to V) it was not always possible to retain the specimens for further study. But in regard to scutes alone, revision of judgment is necessary in a comparatively small number of cases, and a field sketch frequently helps to remove this difficulty.

Regarding the figures, some are photographs, some tracings from photographs, and some camera sketches, while others are field sketches (see *Explanation of Plates*, etc.). No greater accuracy is claimed for the field sketches than that they represent, somewhat diagrammatically, the position, shape and proportionate size of the scutes depicted.

As diversity manifests itself in so many respects, we must of necessity disregard most individual differences, and consider only certain defined "abnormalities." In the tables that follow, a turtle is "normal," unless it possesses *more or less than the number of scutes* typical of the species, shows instances of *partial division* or *partial fusion* of scutes, has a median plate marked with a *distinct and complete median groove*, exhibits such asymmetry as with *one scute of a pair twice as large as its mate*, or has scutes not firmly united to the bone.

TABLE I.

Malaclemmys centrata (Latr.), Beaufort, N. C., 1902.

SCUTES.														Figures.
Serial Number.	Length of Plastron in inches.	Sex.	Rings of Growth.	Nuchal.	Neural.	Costals.		Marginals.		Inguinals.	REMARKS.			
						Left.	Right.	Left.	Right.					
1	2.6		2	1	5	4	4	12	12		Normal.			
2	2.7		2								Normal.			
3	2.7		2	f										
4	2.7		2		5	5	4	11	11	L R	M11 broad, evidently representing normal 11 and 12; minute scute anterior to LC1.		20	
5	2.8										Normal.			
6										R	R. inguinal small.			
7			2						11	11		(See remarks on M11 of No. 4)		
8			3								L	Supn'y costal small, anterior, L axillary ½ R in size.	3	
9	3	♀	3			4	5						4	
10	3													
11			2								Normal.			
12														
15			2								Normal.			
16	3.2		2								Normal.			
17	3.5		4								Normal.			
18	3.5	♂									Normal.			
19	3.5	♂									Normal.			
20	3.6	♂									Normal.			
23	3.6	♂												
24		♂								L R				
25		♂												
26		♂												
27	3.7	♂									Normal.			
28	3.7	♂	5							L R				
29	3.8	♂	x								Normal. No. 29 with 8 rings; Nos. 30 and 34 with 5.			
34	3.8	♂												
35		♂						13	13					
37		♂												
38		♂			x				13	13		Pair of scutes between N5, C's 4 and M's 12 and 13 (= 5th pr. of costals, or 6th neural divided?) Supn'y marginal posterior.		
39	3.8	♀								L R				
40	3.8										Normal.			
41	3.9	♂									Normal.			
43		♂									Deep notch between last pair of marginals.			
44	3.9	♂	pr							L R	Deep notch between RM10 and 11 (Scar?).			
45	3.9	♂									L. axillary wanting,			
46	3.9	♂									RM11 and RM12 continuous distally, divided proximally.			
47	3.9	♂						x		R	Normal.			
48	3.9										Normal, except that 2d, 3d, and 4th pairs of plastral scutes overlap, respectively, the scutes immediately posterior			
49											Normal. (No. 53 with 4 rings of growth. Seam between N4 and N5 oblique.)			
50	3.9										Normal.			
51	4.	♂			x						Minute 5th R C. about 1-40 size of 4th. Seam between N4 and N5 oblique.		21	
54														
55	4.	♀												
56	4.	♀			x	4	5							
57	4.	♂								L < R				
58	4.	♂	4							L R	L. axillary wanting.			
59	4.	♂									Normal.			
60	4.1	♀												
61	4.1	♀	3											
62	4.1	♂								L R				
63	4.1	♂				5	4				LC4 reduced.			

(Continued on next page.)

TABLE II.

Malaclemmys centrata (Latr.), Beaufort, N. C., 1903.

(A few from Brunswick County, N. C.)

A.—MALES.

Serial Number.	Length of Plastron in inches.	SCUTES.							Figures.
		Nuchal.	Neurals.	Costals.	Marginals.		Inguinals.	REMARKS.	
					Left.	Right.			
93	3.								Normal.
94 }	3.3								Normal.
95 }	3.6	pr							R axillary $\frac{1}{2}$ of L in size.
96 }	3.6								Axillaries wanting.
97 }	3.6								Normal.
98 }	3.6								Normal.
104 }	3.7								Normal.
105 }	3.7				13	13			M13 small.
107 }	3.8								Normal.
108 }	3.8								Axillaries not fixed to bone beneath,
109 }	3.8								but movable; L < R.
113 }	3.8								
114	3.8								
115	3.8						R		
116 }	3.8	f							
117 }	3.9								
120 }	3.9								R axillary twice as large as L.
121 }	3.9								
122 }	3.9						L R		
123 }	4.								Normal.
124 }	4.2	pr f							
125 }	4.3								

B.—FEMALES.

126	3.				13	13		2 marginals in place of normal M1.	13
127	3.2						R	Normal.	
128	3.3				12	13		2 scutes in place of normal RM12.	
129	3.6							Small LC5.	
130	3.6							2 scutes in place of normal RM1.	9
131	3.7				5	4		Small L costal anterior to normal first.	
					5	4		Supn'y plastral scute between femoral and anal of R side.	K
132	3.9							Small 5th. LC.	
133	3.9				5	4		Normal.	10
134	3.9							R axillary twice L in size.	
135	3.9							Normal.	
136 }	4.							L inguinal small.	
137 }	4.						L	Small scute between N1 and 2, similar in size and shape to supn'y scute of No. 150, but entirely to left of median line and without keel. (Cf. fig. 6 of No. 150.)	
138	4.								
139	4.	x							
140	4.						R		
141 }	4.1								
142 }	4.1						L R		
143	4.2				x	x	R	LM11 is less than $\frac{1}{2}$ LM10 in size; RM11 is less than $\frac{1}{4}$ RM10.	
144	4.2							Normal.	

(Continued on next page.)

(Continued from preceding page.)

SCUTES.										
Serial Number.	Length of Plastron in inches.	Nuchal.	Neurals.	Cos- tals.		Marginals.		Inguinals.	REMARKS.	Figures.
				Left. Right.	Left. Right.					
145	4.3					13			Supn'y M posterior to LM3, barely showing dorsally. L abdominal and R femoral meeting for more than $\frac{1}{4}$ mesial border of femoral.	37 38
146 }	4.4								<i>Normal.</i>	
148 }	4.4		x	?			L < R		2 scutes occupying place of N5. Ing.	11 D
149 }	4.4		x							
150	4.5		x						Small scute anterior to L side of N4, extending barely over median line and bearing keel prominence.	6
151	4.5		x	4 5	12 13				Region of N3, N4 and N5 occupied by 6 scutes, the last incompletely divided. L axillary wanting, R small.	7 15
152	4.5		x				L R		Seam between N4 and N5 distorted slightly.	
153	4.5				x x				<i>Normal</i> , except that LM12 and RM-12 were very narrow proximally ($\frac{1}{2}$ width of 11) but of usual width distally.	
154 }	4.5								<i>Normal.</i>	
156 }	4.6								L axillary wanting.	
157 }	4.6						L R			
158 }	4.6								<i>Normal.</i>	
159 }	4.6									
160 }	4.6									
161	4.7		x				L R		Inguinals small. Seam between N4 and N5 distorted.	E
162	4.7		x		13 13				Seam between N4 and N5 oblique.	
163	4.8								<i>Normal</i> , but axillaries small.	
164	4.8						L		L inguinal small.	
165 }	4.8								<i>Normal.</i>	
166 }	4.8									
167			x	5 4					N3 incompletely divided, N4 represented by 2 scutes.	16
168	5.3	pr	x				L R		2 scutes in place of N5.	
169	5.3						L R			
170	5.4								<i>Normal.</i>	
171	5.5									
172	5.5								<i>Normal.</i>	
173	5.6						R			
174	5.9				x x		L R		12th margi'ls asymmetrically placed, LM12 having a position in median line.	26
175	6.4						R			
176	6.8					x			RM's 2 and 3 fused proximally.	34

TABLE IV.

EMBRYOS AND NEWBORN—*Malaclemmys centrata* (Latr.).

Serial Number.	Length of Plastron in Inches.	Length of Carapace in Inches.	SCUTES.										REMARKS.	Figures.
			Nuchal.	Neurals.	Cos- tals.		Margi- nals.		Inguinals.					
					Left. Right.	Left. Right.	Left. Right.	Left. Right.						
227	.32	.52	f										3 scutes in the place of N5.	22
228	.35	.51	pr	x			13	13					Normal.	
229	.40	.58												
230	.45	.65							L	R			Inguinals small; slight notch in nuchal anteriorly.	
231	.62	.77	x						L > R				Normal.	
232	.71	.92											Very abnormal in shape but scutes	(25 L
233	.78	.76		x	4	5	12	12					adhere to typical series arrangement; neural scutes most abnormal (v. fig.25). Supn'y scute in L series of plastron posteriorly. L axillary wanting. A R inframarginal?	
													Normal.	
234	.78	.99											Normal.	
235	.80		x	x	x		13						Misshapen: nuchal pushed over to R side; 12th L marginal represented by 2 scutes, LC4 reduced, N6 wider on L side. Posterior part of plastron shortened and distorted; large umbilical scar. (About 7 months old. Hatched from eggs laid in confinement.)	
													Normal.	
236	.90	1.00											Normal.	
237	.95	1.11			4	5							Normal.	
238	.96	1.14											Normal.	
239	.96	1.15											Normal.	
240	.98	1.08							R				About 7 months old. Hatched in pound at Crisfield, Md.	
241	.99	1.16											Normal.	
242	1.10	1.24											Normal. (Cf. note on No. 240.)	
243	1.11	1.23							L	R			(Cf. note on No. 240.)	

TABLE V.

SELECTED ABNORMAL TERRAPIN—*Malaclemmys centrata* (Latr.).

SCUTES.										Figures.
Serial Number.	Length of Plastron in inches.			Costals.	Marginals.		REMARKS.			
		Nuchal.	Neurals.		Left.	Right.				
244		pr	x	5	5			Median furrow on anterior portions of N1 and N2; supn'y costals anterior.	2	
245	(3.)	pr		5	5	11		Supn'y costals anterior; LM11 nearly equivalent to RM11 and 12. (Carapace distorted in drying, and broken at "x".)	18	
246	3.5		x	5	5			Supn'y costals anterior and small; seam between N4 and 5 distorted slightly.	19	
247	3.4		x					N5 represented by a large and a small scute. (Note that, with seam removed there would be a scute of nearly normal size, and that the areolae together would make a normal areola.)	24	
248	3.6					x		One medium, one small, and one minute scute occupying place of LM9—(Wound?).	40	
249	3.6	pr	x	x	x	x	x	Asymmetry of scutes and distortion of seams in posterior region of carapace (Neurals, Costals and Marginals).	36	
250	3.6		6	6	4	12	13	v. fig. 50, also description p. 26.	50	
251	3.6		x	5	4			7 scutes in neural series (2 in place of 4th).	14	
252	4.		x				x	5th neural represented by 2 scutes of unequal size; RM12 incompletely divided.	49	
253	4.3							Small L inguinal.	F	
254	4.3							Large inguinals; small scute immediately anterior to L inguinal.	G	
255	4.6	x		5	5	13	12 x	Of abnormal shape; 12th L marginal represented by 2 scutes; only 12 R marginals, but between RM11 and RM12, a small gap occupied by soft skin. Supn'y costals posterior; also a very small scute between LC4, LC5 and marginals. Nuchal partly divided; inguinals. (Vertebral column distorted to left posteriorly. L side of carapace flattened, somewhat concave posteriorly. Shell suggestive of injuries rec'd in embryonic stage. Evidence of much shedding, horny covering thin and smooth.)	39	
256	4.6		x	?	?	13	12	RM12 equivalent to LM12 and 13. 4 scutes occupying a space almost exactly coinciding with that of normal N5. Small inguinal.	23	
257				5	4			LC3 followed by two scutes, which together are almost exactly equivalent to a normal C4 (cf. RC4).	27	

PART I. MALACLEMMYS.

The observations are presented as made on individual specimens in the tables of Section 1, and are treated in classified form in Section 2. The classification of abnormal neurals and costals leads to the discussion of adjustment of neurals and costals which forms the subject of Section 3.

1. OBSERVATIONS.

The first 243 specimens that could be observed carefully are included in Tables I to IV. These tables may, therefore, give a fair idea of the proportion of "abnormal" individuals in this species.

Table V includes a few specimens that were selected from a considerable number of others that have come under observation.

2. REVIEW OF OBSERVATIONS.²*Inframarginals.*

The *inguinals* are by far the most common scutes not typical of the shield of this species. No less than 21 per cent of the 243 specimens possessed one or both inguinals. In 33 individuals inguinals were present on both sides (v. Figs. D and E), but in 4 of these a distinct difference in size was noted between the scutes of the pair. Seventeen specimens had inguinals on only one side (Fig. F). *Axillaries* were wanting in only one terrapin, but were quite small in two others. In 5 specimens one axillary was wanting (Fig. L), and in 4 others one scute was at least twice as large as its mate of the opposite side (Fig. 4). Another individual (No. 114) had axillaries of normal appearance, but they were found to be loosely attached to the bone beneath, the skin connecting them with the adjacent scutes permitting a certain freedom of movement when the axillaries were pressed with the finger. It may be noted from the tables that a right inguinal occurred alone 12 times as opposed to 5 instances of the left alone, and the right was distinctly larger than the left 3 times as against a larger left once; also, while the right axillary occurred without the left 5 times, the left without the right was not noted. The right axillary was twice as large as the

²Numbers and percentages refer to Tables I to IV, unless otherwise stated.

left in 3 specimens, while the left was three times as large as the right in one terrapin. In Table V the left inguinal occurs twice without the right (Fig. F) and both are found in Nos. 254 (Fig. G) and 255. An additional scute in this "inframarginal series occurred in one or two specimens: in 254 and possibly in No. 233. (Figs. G and L.)

Interplastrals.

The shield of *Malaclemmys* has normally no interplastral scute, and such a scute was found to be a very rare abnormality, as it occurred only in Nos. 75 and 181. In both cases it was small and

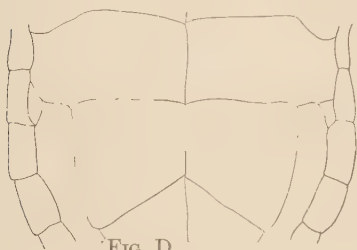


FIG. D.



FIG. E.



FIG. F.

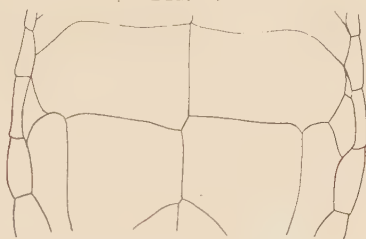


FIG. G.

FIG. D. Plastron of No. 149, showing unsymmetrical pair of inguinals.

FIG. E. Plastron of No. 161, showing paired inguinals.

FIG. F. Plastron of No. 253, showing left inguinal.

FIG. G. Plastron of No. 254, showing pair of large inguinals and a small scute anterior to left inguinal.

situated at the meeting-point of gulars and brachials (Fig. H, cf. Fig. B). In some species of turtles a large scute in this position is a normal feature of the shield (Fig. I). I do not know of any species in which characteristic interplastrals occur elsewhere. New-

mann has observed interplastrals, as abnormalities, at other points, but always at the meeting-point of four plastral scutes.

Plastrals.

The plastral scutes (cf. Fig. B) are remarkably constant; only two supernumerary scutes were noted. No. 132 showed an anomalous scute between the femoral and the anal of the right side (Fig. K), and in No. 233, two scutes occupied on the right side a space equivalent to that occupied by the femoral on the left (Fig. L). No. 88 presented an interesting abnormality discussed in a former paper ('05 a, pp. 14-18 and Fig. 6). In this specimen, the abdominal and femoral scutes were entirely separate to a certain point, but the last three rings of growth were perfectly continuous between the two scutes internally or mesially (Fig. M).



FIG. H.

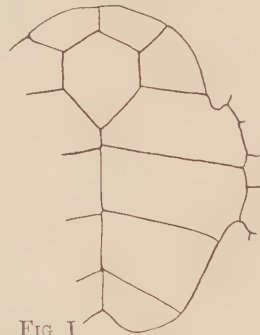


FIG. I.

FIG. H. Anterior portion of plastron of No. 181, showing small "inter-plastral."

FIG. I. Part of plastron of a species of *Chelodina*, showing large "inter-plastral."

In at least one species of turtle *Eretmochelys imbricata*, the scutes of the shield (Car. and Plas.) are imbricate and are said to be added to anteriorly as they wear away posteriorly. In the carapace of *Malaclemmys* the scutes are not imbricate, but they grow more in the anterior and lateral directions than in the posterior direction. In the plastron, however, there are often traces of overlapping posteriorly, especially in young shells. The posterior part of the rings of growth, usually very narrow, may be particularly so in such specimens, or even entirely wanting, the mesial segments of the

rings ending abruptly at the posterior margin which overlaps the next scute. The overlapping was particularly striking in No. 50.

No. 145 was characterized by marked asymmetry of abdominal and femoral scutes (Figs. 37, 38, Pl. IX).

Marginals.

Except in two malformed shells, supernumerary marginals occur only in the regions anterior to the normal position of M 3, and posterior to that of M 10. This means that none occur except anterior or posterior to the region of the dorsal ribs. The exceptions are Nos. 145 and 248 (see Figs. 37 and 40, Pl. IX, and "Remarks" in tables). Anterior supernumerary scutes were found in Nos. 126 and 131 (Figs. 13 and 9). In each of these the first two marginals (R and L in No. 126, R in No. 131), taken together, are about equivalent to a normal first marginal. In No. 210 (Figs. 5 and 17) the first right marginal was partially divided.

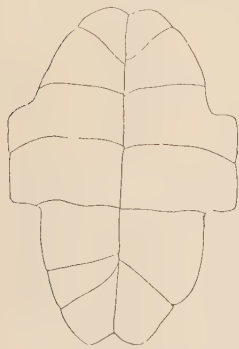


FIG. K.

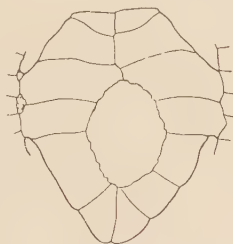


FIG. L.

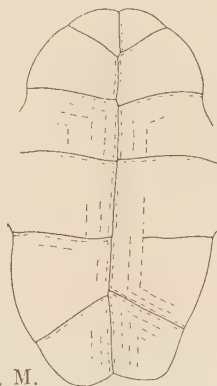


FIG. M.

FIG. K. Plastron of No. 132, showing anomalous scute on right side posteriorly. FIG. L. Plastron of No. 233, supernumerary scute on left side.

FIG. M. Plastron of No. 88, left femoral and abdominal continuous mesially.

Abnormalities are more common in the posterior region, additional marginals being observed on the left side in No. 235, on the right in Nos. 88 (Fig. 12), 129, 151 (Fig. 7), 183 (Fig. 33); on both sides in Nos. 35, 36, 37, 38, 108, 162, 178 (Fig. 30), 196 (Fig. 42), 198 (Fig. 45), 209 (Fig. 32), and 228 (Fig. 22); cf. also Table V, Nos. 250 (R), 252 (R), 255 (L) and 256 (L) and figures.

Sometimes the marginal series shows a reduced number of scutes. Thus Nos. 4 (Fig. 20) and 8 had only eleven pairs of marginal scutes, the eleventh marginals being very long. No. 245 had only eleven on the left side (Fig. 18) and the two posterior scutes of the left side, taken together, are equivalent in size to the last three on the right. Partial fusion of 11 and 12 (R) was noted in No. 47 and of 2 and 3 (R) in No. 176 (Fig. 34). In Nos. 153, 174 and 185, the twelfth marginals were reduced in size, and, in the latter two specimens, were asymmetrical (Figs. 26 and 29).

Nuchal.

The most interesting abnormalities of scutes are those shown by the nuchal and the neurals. The most anterior of the median scutes of the carapace is always given the name *nuchal*, but is generally included with the other median scutes in the neural series. It resembles the other neurals in being median and usually unpaired, but differs from them in some evident respects. Its direction of predominant growth is the reverse of that of the other median scutes. It is absent in some existing species and in the fossil turtles of the genus *Pleurosternum* Owen, belonging to the sub-order *amphichelydia* Lydekker, a group which von Zittel regards as ancestral to the modern Pleurodires and Cryptodires ('02). I find it occurring in paired condition or marked with a median furrow much more frequently than any other commonly unpaired scute of the carapace. In this connection the frequent evagination of this scute in *Clemmys guttatus* is of interest.

The nuchal was represented by a pair of scutes in ten specimens: Nos. 44, 74, 78, 97, 124, 168, 196 (Figs 31), 200, 210 (Figs. 5 and 17), and 228 (cf. also Table V, Nos. 244, 245 and 249, and figures). A distinct median furrow, not distinguishable as a seam, occurred in nine individuals: Nos. 3, 73, 116, 125, 182, 185, 208, and 211; a faint median furrow was observed in No. 80.

Costals.

It will be observed that abnormal scutes occur much more frequently in the posterior costal region than in the anterior.

Typically, each costal series consists of four scutes, which dovetail between the five neurals. The seam between C1 and C2 meets the fifth marginal near its anterior end, and the succeeding costal seams meet alternate marginals (seventh, ninth and eleventh). These typical relations of the costals to the shields of the other series, may aid in the diagnosis of supernumerary scutes (v. Fig. A).

In Fig. 9 the first large scute in the L. costal series shows essentially the relations of the normal first costal, so that the small scute anterior to it may fairly be considered the supernumerary element. Such anterior supernumerary costals may occur on both sides, approximately symmetrically (Nos. 244, 245, and 246, Pl. I, Fig. 2, and Pl. VII, Figs. 18 and 19); or on both sides but quite asymmetrically (No. 218, Pl. IX, Fig. 41), or on only one side (No. 9, right side, Pl. II, Fig. 3, and Nos. 4 and 131, left side, Pl. VII, Fig. 20, and Pl. V, Fig. 9). In each case referred to above, the extra scute was small in comparison with the other costals. In No. 218 supernumerary scutes were observed both anteriorly and posteriorly (Figs. 41 and 44).

Perhaps some of the cases to be discussed below belong in one of the above classes. In Nos. 210 (Figs. 5 and 17) and 151 (Figs. 7 and 15) the supernumerary scute in the costal series may be the large C1; but it would be difficult if not impossible to determine in these instances whether the first or second scute is to be regarded as supernumerary. We must always recognize the possibility that in some cases we are not presented with the four normal scutes as individuals plus an extra, "supernumerary," individual, but simply with a five-scute series instead of a typical four-scute series. Furthermore it may be quite immaterial whether an anomalous scute is termed a neural or a costal; the designation may be without real significance. Of course, however, if supernumerary scutes are attributed a morphological value, their proper classification is of the first importance (cf. below, p. 42).

The difficulty of identification of scutes is enhanced in the posterior region, where it is often difficult to decide whether a given anomalous scute is to be classed as a neural or a costal [cf. Nos. 210 (Figs. 5 and 17) and 252, Fig. 49]. It was found necessary to adopt certain rules of classification which may be in some measure

arbitrary. They are based on the fact that the seam between C4 and N5 typically meets M11 at a point near the middle or anterior part of its inner border (Fig. A, etc.).

1. (a) In a specimen with the usual number of twelve marginals, any scute in order with the costals which does not extend positively beyond M11 is considered a costal. This rule certainly becomes arbitrary when applied to small scutes which extend neither anteriorly nor posteriorly to M11, and which may, therefore, be as much within the neural region as within the costal region (Pl. VII, Fig. 21). It is convenient, however, to class such elements with the costals.

Compare:

much within the neural region as within the costal region (Pl. IV,

- No. 56, Pl. VII, Fig. 21, small scute, right side
- No. 133, Pl. V, Fig. 10, small scute, left side
- No. 167, Pl. VII, Fig. 16, large scute, left side*
- No. 217, Pl. X, Fig. 46, large scute, right side†
- No. 218, Pl. X, Fig. 44, medium scutes, both sides
- No. 250, Pl. XI, Fig. 50, small and medium scutes, left side
- No. 251, Pl. VII, Fig. 14, medium scute, left side
- No. 255, Pl. IX, Fig. 39, small scute, right side
- No. 256, Pl. VII, Fig. 23, medium scute, right side
- No. 257, Pl. VIII, Fig. 27, LC4 represented by two scutes

(b) Sometimes extra marginals occur in association with extra costals; in such cases, the costal region may be supposed to extend to the twelfth marginal, which is the next to last, as is the eleventh in the typical series. Therefore, if there are thirteen marginals, a scute in order with the costals, which does not extend posteriorly to M12, is classed as a costal.

Compare:

- | | |
|---------------------------------|--------------------------|
| No. 151, Pl. { IV } Fig. { 7, } | large scute, right side* |
| { VII } Fig. { 15, } | |
| No. 196, Pl. IX, Fig. 42, | medium scute, left side |
| No. 198, Pl. X, Fig. 45, | small scute, each side |
| No. 255, Pl. IX, Fig. 39, | small scute, left side |
| No. 256, Pl. VII, Fig. 23, | small scute, left side |

2. If, in a specimen with twelve marginals, a scute in order with the costals extends barely over on M12, but in its anterior

*In the left costal series of this specimen, the supernumerary costal may, of course, be one of the more anterior scutes.

†No. 217 is incorrectly included in this list. It may properly pertain to the next list (b), but is a very doubtful case.

part is in contact with M10, it may fairly be regarded as a terminal costal that encroaches slightly on the neural region.

Compare:

No. 195, Pl. III, Fig. 8,	medium scute, left side
No. 199, Pl. X, Fig. 43,	medium scute, left side
No. 210, Pl. { III, } Fig. { 5, }	medium scute, left side*
{ VII, }	
and, possibly,	
No. 181, Pl. X, Fig. 47,	medium scute, left side
No. 149, Pl. IV, Fig. 11,	large scute, left side

3. A scute which overlaps the last marginal and is not in contact with any marginal anterior to the next most posterior (M11, in typical marginal series), is within the neural region and must be classed as a neural.

Compare:

No. 222, Pl. X, Fig. 48.
No. 252, Pl. XI, Fig. 49.
No. 256, Pl. VII, Fig. 23, small scute on right side.

It is doubtful whether the extra scutes on the left in Nos. 149 (Pl. IV, Fig. 11) and 181 (Pl. X, Fig. 47) should be included in this or the preceding class. The small scute on the right in No. 247 (Pl. VIII, Fig. 24) would seem to belong in the first class, but the shape of the areolæ of this and of N5 and its manner of growth as indicated by the rings suggest clearly that it is but the separated lateral end of N5.

It may be that this scheme of classification, as applied to such specimens as No. 198 (Pl. X, Fig. 45) and 256 (Pl. VII, Fig. 23) is quite arbitrary. This leads to the general question whether the reference of many of the abnormal scutes to normal series has any other merit than that of convenience of description. This question will be referred to in a later section, but it is well to make clear the difficulty of identification because, if abnormal scutes are to be regarded as of morphological value, rational and exact classification is essential.

The difficulty of diagnosing the costal series of cases like No. 151 (Figs. 7 and 15, right side), 167 (Pl. VII, Fig. 16, left side) and 210 (Figs. 5 and 17, both sides) has been referred to. In No. 210,

Cf. footnote () preceding page.

for example, the seam between the second and third shields of the right costal series, meets M5, and this is the usual position of the seam between normal C1 and C2. Considering this seam as corresponding to the normal seam between C1 and C2, we note that the following costals (C3 to C5 in this shell) have exactly the relations to the marginals normal for costals 2, 3 and 4. We have only to assume that normal C1 is represented by two scutes in this carapace, or that one of the first two scutes is supernumerary; the right costal series is thus made perfectly intelligible by considering its relations to the marginal series, and disregarding its relations to the neural series. Turning to the left costal series, the four large scutes present a perfectly normal appearance, and have nearly normal relations to the lateral apices of the neural series; yet not one of the four has normal relations to the marginals, though the marginal series of each side is nearly normal. This series would be intelligible if we disregarded the marginal relations. Either series is interpretable, provided we do not apply the same criteria to both sides. It is clear that the exact identification of supernumerary scutes must often be impossible or quite arbitrary. The significance of such cases will become clearer after the following section.

Neurals.

Excluding the nuchal, for present purposes, the neural series consists typically of a row of five median scutes, which dovetail laterally with the costals. The first four usually bear marked prominences, which together form a low serrated keel. The fifth, sometimes, especially in younger specimens, shows a very low and inconspicuous continuation of the keel (cf. Pl. VI, Figs. 12 and 13). This keel is suggestive of the serrated dorsal keel of the tail of *Chelydra*, and Hay and Newmann regard the neural scutes as serially homologous with the scutes of the dorsal keel of the tail of *Chelydra*. In view of the accredited phylogenetic significance of the keel prominences they may aid in the interpretation of supernumerary scutes in the neural series. Such scutes are almost always placed not symmetrically, in longitudinal sequence, or alongside of each other, but asymmetrically and wedged in together. The photographs

are most instructive. In Fig. 8, Pl. III, there are at least seven elements in the neural series, of which the most posterior five fit in together as if crowded out of a condition of longitudinal sequence, each scute extending across the median line. It will be noted that while the rings of growth indicate that each scute has grown most in the antero-external direction (toward the antero-lateral costal), yet each scute shows comparatively broad rings toward its antero-mesial neighbor of the same series, although growth in this direction must cause further distortion of the keel by pushing the prominences further and further away from the median line. Nevertheless the prominences still make a continuous but crooked carapace keel. No. 151 (Fig. 15) presents a different condition. Numbering the scutes from N1 posteriorly, (cf. Pl. IV, Fig. 7, of the same carapace) N3 and N5 are almost parallel in position to N4, and the keel of N5 extends anteriorly half-way by the keel of N4, to which it is exactly parallel. Clearly, in this case the keel of the carapace branches and is double for a part of its course.

No. 150 (Pl. IV, Fig. 6) may offer a clear case of longitudinal sequence, though the supernumerary scute is largely on the left side. No. 139 had a very similar anomalous element, but entirely to the left of the median line and without the keel prominence.

Nos. 167 (Pl. VII, Fig. 16) and 251 (Pl. VII, Fig. 14) are comparable to the first illustration given above.

In the cases cited, which are representative of a number of others, the keel prominences throw no definite light on the question at hand. Is it to be assumed that such scutes are primarily in longitudinal sequence but are crowded out of position? Or that they are really paired scutes, asymmetrically placed? Or is their significance something still different? Newmann has decided in favor of the first explanation, but suggests that Gadow would probably consider such types as evidence of the original paired character of the neural row.

It is possible *hypothetically* to regard many of the asymmetrical neural anomalies as illustrating only a *secondary* asymmetry, a *modified* longitudinal sequence; but some cases can hardly be referred to such a condition, especially when a portion of the keel parallels another portion, as in No. 151 described above. Now, is

the keel necessarily a single structure which we must not expect to find divided? So far as I know, there is no phylogenetic evidence of the neural series of turtles ever having been paired, or, of a double dorsal keel in primitive turtles (cf. Newmann, '56, p. 92). If we must regard these abnormalities as atavisms, we can hardly conceive of the atavism taking so often the form of paired supernumerary neurals; we would be led to assume, with Newman, that we were presented with a modified longitudinal sequence. Now, disregarding atavism for the moment, we will consider the anomalies as we find them.

No case of unmistakably paired neurals has been observed in the terrapins of North Carolina or Maryland, if we exclude the nuchal, which is, however, usually included in the neural series; but there are interesting abnormalities that are significant in this connection. The nuchal, as has been seen, is sometimes paired, sometimes marked by a median furrow in the position of the seam, and the furrow may be so marked as to make it difficult to distinguish from a seam, or there may be a seam on the anterior half of the scute, continued posteriorly by a furrow (*Thalassochelys*, Pl. XIII, Fig. 89, and Pl. XIV, Fig. 94). Apparently the difference between the furrow and the seam is that the furrow divides incompletely, while the seam divides the scute completely as far as the seam extends. Now in four specimens of *Malaclemmys* (Nos. 73, 78, and 211; also No. 244 of Table V), some of the neurals were marked by a median furrow similar to the furrows observed on nuchals, and in each of these cases the nuchal was either marked with a furrow, or paired. Especially suggestive is No. 70 (Pl. I, Fig. 1) where N2 shows a short furrow on the anterior rings,³ and N4 has all of its rings intersected anteriorly by a seam. Compare also Pl. I, Fig. 2, of a terrapin with nuchal paired and with furrows on N1 and N2.

In logical sequence with these specimens come some terrapins (*M. littoralis*) from Texas. In a small number of specimens placed by Mr. W. P. Hay in the United States National Museum, we observe all stages from very incomplete to complete division of the

³Owing to the manner of reflection of light the furrow on N2 is not apparent in the photograph, though very evident in the shell.

neural series (Figs. 53 and 54).⁴ (See also W. P. Hay, '05,

⁴These specimens are of peculiar interest on account of the precise median longitudinal division of neural scutes (partial or complete)—a rare abnormality, though common, apparently, in the specimens from this particular region.

NINE SPECIMENS OF *MALACLEMYS LITTORALIS* HAY.

No.	Length of plastron in inches.	Median longitudinal division of scutes, as follows:
258	4 $\frac{5}{8}$	N2 with seam complete except in anterior portion of areola (oldest portion of scute), and in first (most posterior) part of anterior ring of growth. N3 similar to N2, except that seam, anteriorly, arises a little later.
259	4 $\frac{3}{4}$	Nuchal paired. N1 partially divided posteriorly. N2 completely divided. N3 partially divided anteriorly and posteriorly. <i>Fig. 53.</i>
260	6 $\frac{1}{2}$	N2 and N3 divided except for areolæ. <i>Fig. 54.</i>
261	7	N1 with furrow anteriorly.
262	7	N3 partially divided anteriorly and posteriorly.
263	7	Nuchal paired. N2 divided except areola. N3 partially divided anteriorly and posteriorly.
264	7 $\frac{1}{8}$	N2 partially divided anteriorly and posteriorly. N3 divided except areola.
265	7 $\frac{1}{4}$	N3 slightly divided anteriorly—that is, just beginning to show division.
266	..	Only third and fourth neurals present; N3 marked anteriorly by faint furrow.

It appears that only a few of these scutes (possibly only N2 of 259, Fig. 53) were split at birth; some others (as N2 and N3 of 258) were divided only in the posterior portion of the scute (of course, the areola of the older stage represents the entire scute of the newborn turtle); while in others the division, anteriorly and posteriorly, appeared at various subsequent stages. In

regarding the abundance of such forms.) A young specimen of *Chelydra* in the zoological museum of the Johns Hopkins University has its keel marked with a distinct sagittal furrow which extends from the anterior margin of N1 to the posterior margin of N5, and is continuous through all of the keel spines except that of N5; such a furrow is seen less distinctly in the shells of older turtles.

In the light of these median furrows and incomplete and complete seams, and of the parallel keel prominences of No. 151, there would seem no inherent improbability of duplication of the median keel or of neural scutes, nor any necessity for explaining away appearances of duplication. To jump to the other conclusion, that the asymmetrical neurals are primarily paired scutes which are crowded out of a symmetrical plan, would be equally unwarranted. "Crowding" may be, at best, but a descriptive term referring only to the appearance presented, rather than to any organic phenomenon.⁵

May it not be that we have to do here neither with scutes in sequence nor with paired scutes, but with a real asymmetry of scute plan? Symmetry is a normal feature of the carapace, but the cases in question are admissably abnormal, and, on the face of it, the scutes are asymmetrically disposed. The question is thus: Is the visible asymmetry secondary and due to the crowding out of line of elements that are primarily symmetrical, or is there in such cases a real primary, though abnormal, asymmetry, which is perhaps correlated with some other asymmetry? The almost invariable association of asymmetry in number or arrangement of the costal scutes is strongly suggestive of the latter conclusion. Granting some primary abnormality arising either as a germinal variation or in consequence of environmental conditions, it may be that the conditions of growth cause the development of the neural scutes neither in linear sequence nor in pairs, but in essentially such an asymmetrical plan as is presented by the cases in question.

these nine terrapin fifteen neural scutes, besides nuchals, show some degree of division. Hay states that the longitudinal division of scutes was "so common that it was really difficult to pick out a full-grown specimen which did not show it in some degree."

"Extra marginals may be small or large but do not seem to be "crowded" out," and the same may be said of extra costals.

The asymmetrical neurals lead us to the subject of the inter-adjustment of neurals and costals, a subject of sufficient significance to justify its treatment in a separate section.

3. ADJUSTMENT OF NEURALS AND COSTALS.

In the typical carapace, neural scutes and costal scutes have an alternating relation. The neural series dovetails on each side into the costal series and a neural seam extends transversely from the apex of each costal scute. Extra scutes may occur in different parts of the costal series and often only on one side. In cases where the abnormality is such as seriously to disturb the symmetry of the costal series, the adjustment of the neurals to the costals might be accomplished in one of several ways.

1. The sequence of neurals might remain normal, presenting some such appearance as is represented in Fig. N, I.⁶ Such an arrangement of neurals without regard to the costals of one side has not been observed.

2. Neural scutes might have normal relations to costals on each side (cf. Fig. N, II). There would have to be one supernumerary neural in correspondence with the supernumerary costal, and some of the median scutes would occupy oblique positions. In such a carapace, the antero-posterior extent of a neural scute measured from the plane of its most anterior point to that of its most posterior point would be unusually great. The antero-posterior extent of N3 in the figure is indicated by the line *x y*. Disregarding temporarily some rare and partial exceptions, this plan of adjustment is not observed.

Asymmetrical costals often occur in such form as to give opportunity for plans something like one of the above, and these plans seem to offer the simplest schemes of adjustment for neurals. Since with the partial exceptions that will be mentioned later, neither of those plans is observed, we may assume that these hypothetical schemes do not accord with the laws of growth.

3. Assuming that a better coördinated carapace results when,

⁶In Fig. N the costal series is traced from an actual specimen (No. 151) and the same series is used in all three plans.

(a) on each side there is practically the usual relation between costals and neurals, and (b) neural scutes have not an antero-posterior extent that is relatively unusually great, we may imagine such a plan of neurals as is represented in Fig. N, III. On each side neural and costal scutes alternate in position, and the two series dovetail together in usual fashion, while cross seams so divide the neural area that no individual scute has an excessive antero-posterior extent. This plan is not a hypothetical one, as were the others, but is an inference from the observations. Compare with it the plan of scutes illustrated by Nos. 151 (Figs. 7 and 15), and 195 (Fig. 8).

The first two types of adjustment assumed above (hypothetical) may thus be defined:

1. Neurals with *normal adjustment* to costals on one side, but not on the other. Individual scutes show this plan very rarely.

2. Neurals with normal adjustment to costals on both sides, but with the two sides of the neural series related in a way that is rarely observed.

The third type (observed) may be defined thus:

3. Neurals with normal adjustment to costals on each side; the two sides of the neural series unsymmetrical and so related to each other that the plan of each side is largely restricted to that side.

In this manner of growth, then, we have a neural plan (or *half-plan*) on one side, a different neural plan on the opposite side, and each plan is adapted to the costal plan of the same side (cf. the diagram, Fig. O, III a. The mesial region of the carapace is supposed to be covered by a strip of paper). The plan of each side does not usually terminate abruptly in the median line as represented in the diagram, III, b (cf. however, Newmann's Fig. 6),* but the scutes necessary to the plan of one side extend a little over the median line (III, c), sometimes almost or quite across to the opposite costals (III, d). In consequence, we get, not a plan on one side independent of the plan on the other side, but *on each side a plan that is more or less modified by the over-extension of the scutes necessary to the plan of the opposite side.*

*Fig. P, XII.

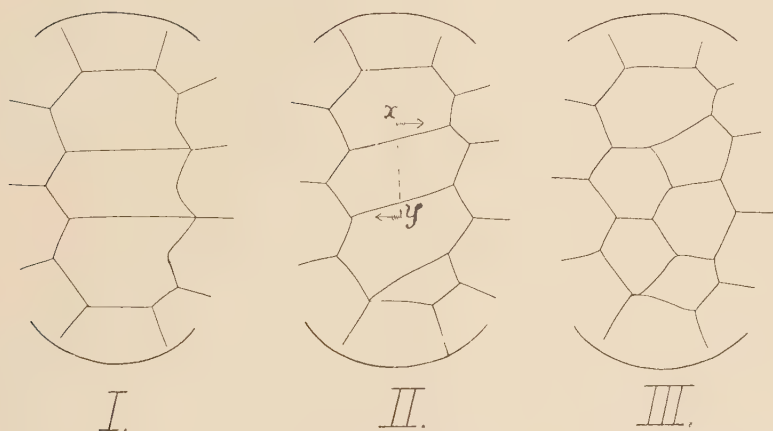


FIG. N. See text.

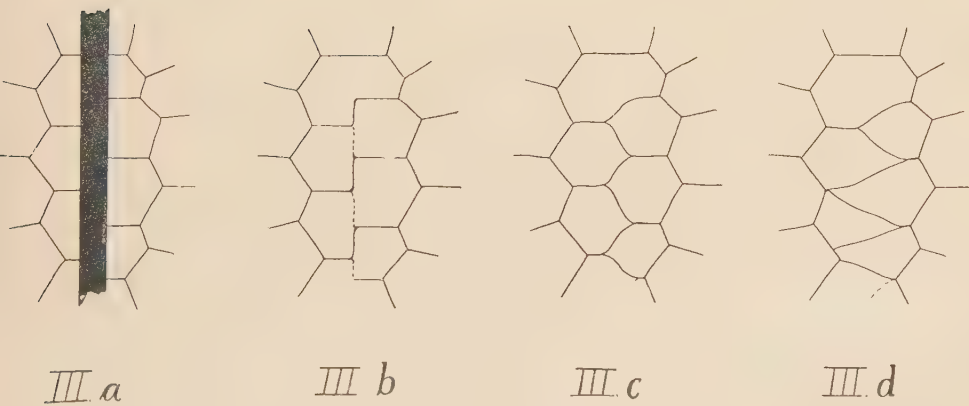


Fig. O. See text.

In the endeavor to make clear the inferred law of growth, I have, in a measure, proceeded in anticipation of the evidence from which the inference was made. The body of the evidence may now be best presented, not by detailed discussion, but by reference to text-figure P, in which are indicated the neurals and costals of a number of specimens. I have drawn freely on Newmann's figures, as his observations include more specimens bearing on this particular point than do my observations on *Malaclemmys*. My observations on another species need not be introduced at this point.

Each carapace figured may be compared, on the one hand, with the types Fig. N, I and II, and on the other hand, with that of Fig. N, III, or Fig. O, III c, and III, d.

It is readily observed that there is no correspondence between the *number* of extra costals and *number* of extra neurals, but that the *region* of "abnormality" in the neural series corresponds in antero-posterior extent with the region of *asymmetry* in the costal region. If asymmetry of costals is confined to a small region, the adjustment of neurals may require only one or two supernumerary elements (cf. Fig. P—V, VI, VII, etc.); but when asymmetry marks a larger part of the costal region the adjustment of the neural involves two, three, or more elements in excess of the normal number (cf. Fig. P—I, II, III, IV).

A few cases which may be classed as partial or complete exceptions require discussion. These are included in Fig. Q, to which refer the Roman numerals in the following paragraphs:

The carapace figured in VI illustrates in part the adjustment supposed. The adjustment would be complete only if a seam united the apices of RC4 and LC5. On any hypothesis this is a remarkably abnormal shield. (From Newmann's Fig. 9.)

In VII there are 5 costals on each side, but the number of neurals is normal. However, the *mesial* region of the two costal series are

"The nuchal and the marginals are omitted in most cases, since they have no bearing on the point in question, and would only complicate the figures. In the subscription full references are supplied, so that the original figures may be consulted if it is desired.

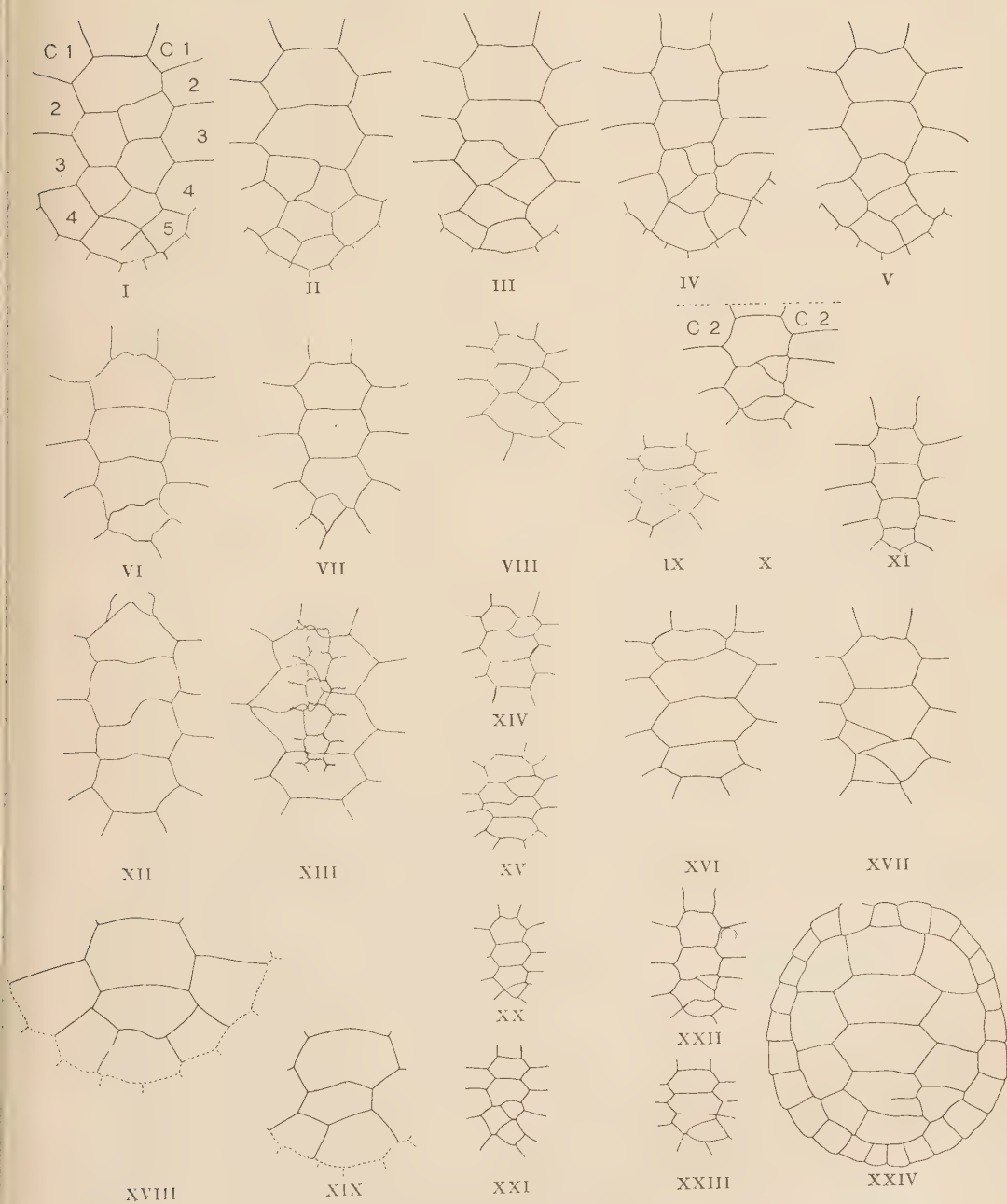


FIG. P. See text.

almost exactly symmetrical, and the second pair of costals are so small at their mesial ends as to be of little significance with reference to the neurals. It may be noted that the second neural is not longer antero-posteriorly than any other scute of the series. (From Newmann's Fig. 25.)

The four next following have an especial interest.

IN I the adjustment appears in the posterior region, but more anteriorly are found two oblique neural elements. The most abnormal, N3, shows an *incomplete seam*, which, were it complete to the point *x*, would be a decided step toward perfecting the adjustment in the manner assumed. (Specimen No. 167, above.)

II presents a very complicated appearance, but the adjustment is more complete than at first appears. Thus, the two interrupted seams, *y* and $\tilde{z}$, are completed by furrows through the areolæ. The adjustment would conform perfectly to the usual plan; had these seams been complete, and had there been a seam in the position of the broken line *x*. The broken lines represent lines of depression of uncertain significance that radiate from the areolæ across the rings of growth (cf., the photograph of this carapace, Pl. II, Fig. 5). (Specimen No. 210, above.)

III represents a carapace that is very abnormal on any hypothesis. Even here, though, there is found an incomplete seam which makes a step in the direction of the assumed plan of adjustment. (From Newmann's Fig. 7).

In the carapace represented by IV, the "law of growth" in question would be fully expressed if the incomplete seam were complete to the point *x*. (From Newmann's Fig. 14.)

Recalling that the growth of the scutes is accomplished by the addition of peripheral rings, and observing that the incomplete seams are in each case in the peripheral or *newer* part of the scute, one may be justified in making the tentative inference that they indicate post-natal attempts to perfect a previously inadequate adjustment of neurals and costals. Certainly they *alter* the plan of adjustment, even if it be a coincidence that the alteration in these few cases is in the direction noted. This occurrence of apparently post-natal divisions in cases of imperfect correlation has been observed in

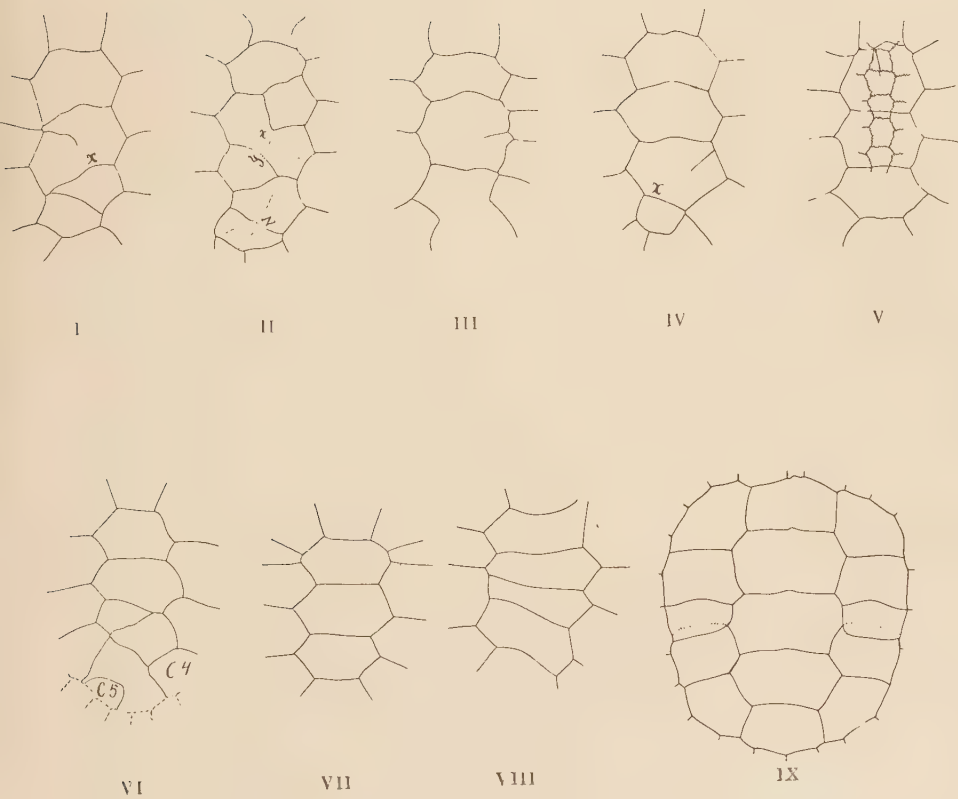


FIG Q. See text.

the relations of marginal scutes and plates and will be seen again in embryos and young of *Thalassochelys*.

V violates the principle of adjustment in the anterior region. The second neural, exceptional in being in contact with three pairs of costals, is incompletely divided, but the significance of the incomplete seam is not evident. (Newmann's Fig. 4.)

VIII presents a very unexpected neural series; but this specimen was an embryo and we do not know how its co-ordination would have stood the test of life, nor whether post-natal seams would have appeared to alter the plan of adjustment. Several of the specimens mentioned above evidently would have shown less conformity if they had been observed in the embryo stage. (Newmann's Fig. 38.)

Another of Newmann's specimens is of particular interest (IX). The carapace is perfectly symmetrical, but there are five pairs of costals and no additional neurals. N3 is in contact with three pairs of costals (C2, C3 and C4). Here is, therefore, a case of mal-adjustment. However, Newmann found that the fourth costals were growing forward underneath the third, and he interprets this as a stage in the suppression of the third ("sixth," in his terminology). If this interpretation is correct, we have the mal-adjustment in process of correction, not, as in other cases, by the partial division of the neural, but by the *removal of the supernumerary* costal. I do not say, however, that the imperfection of adjustment is the cause of the squeezing off.

Hence the exceptions are chiefly partial exceptions, and, on the whole, even these specimens favor much more than they oppose the assumption that the proper *adjustment* of neurals and costals is of more vital importance than mere *number* of scutes. Of course, it is to be expected that turtles will show abnormalities in adjustment as well as in number of scutes; but observation of the relative frequency and degree of deviation from the usual numerical relations, on the one hand, and from the usual adjustment, on the other hand, may be a means of estimating the relative value of adjustment as compared with numerical relations. Supernumerary scutes occur comparatively frequently, while mal-adjustment is rare, and may it not be of some significance that in turtles with imperfect

adjustment, there is evidence of post-natal partial division of scutes by seams that *lessen* the abnormality in *adjustment* while they *increase* the abnormality in *number* of scutes?

There are two classes of costal abnormality that might seem to be exceptional and which, therefore, should be referred to here. (a) When small supernumerary elements occur at the extreme anterior or posterior ends of the costal series (Figs. 10, 21, 23, etc.), without interfering with the symmetrical plan of the normal scutes we would expect no change in the neural series—the adjustment of the series is already practically perfect. (b) Another illustration of asymmetry in *number only* is offered by the division of the 5th costal (Fig. 27). Two scutes may occupy just the position of this shield, without effect on the general plan of the series. On the other hand, of course, asymmetry of costals may occur without supernumerary costal scutes.

To sum up—

In the normal symmetrical carapace neurals and costals have an alternating relation, and the neurals dovetail between the costals. In the unsymmetrical carapace, this relation prevails on each side. It follows that one side of the neural series may be formed according to a different plan than that of the other side. The two opposing plans are independent of each other, but never entirely so. The scutes necessary to one plan extend more or less over into the other side, sometimes even to the opposite costal series, but always in reduced form. The two sides of the body show, at the same time, a degree of mutual independence, with a degree of mutual dependence.

In consequence of these conditions of correlation it is rare to find neural scutes of abnormally great antero-posterior extent, and there is noted a correspondence not between numbers of neurals and of costals, but between the respective regions of abnormality of the two series.

The value of these observations would be lessened if the suggestion of the general applicability of the principle inferred would conflict with previous observations, or with hypotheses which for other reasons we must accept. Previous observations on land and

marsh turtles have been used above); those on sea-turtles will be used in a later portion of this paper.

The only hypothesis which has a bearing is that which regards these abnormal scutes as atavisms. I believe that the general truth of these observations would conflict with that explanation, unless it could be supposed that the reversion was to a stage when neurals displayed the asymmetrical condition observed. In any event, I believe that the upholders of the hypothesis as applied to the scutes in question should account for the following facts:

1. That, generally speaking, more supernumerary neurals are observed in specimens with supernumerary costals on one side than in those with symmetrical supernumerary costals.

2. That, while supernumerary scutes may occur in any one series without additional scutes in any other series, thus indicating the partial independence of each series, yet, when a supernumerary costal occurs in such a position that the *symmetry* of the costal plans is seriously interfered with, the number of supernumerary neurals will depend on the extent of the region of asymmetry.

3. That we do not find asymmetry of costal plan without supernumerary neurals. (See qualification above, p. 41).

There is nothing in these observations to conflict with a supposition that the primary variation, the resulting adjustment of which we see, may be an atavism.

Referring again to the question of the identification of supernumerary scutes—as costals or neurals, etc.—if the adjustment of the whole carapace in accord with the laws of growth is the thing, it is of little real significance whether a given abnormal scute be termed “costal” or “neural,” however convenient such a classification may be for the practical purposes of description.

We have yet to consider the neural and costal scutes in relation to the bony plates beneath, but it is desirable to defer this until after the study of the scutes of *Thalassochelys*, which must conclude the present paper.

4. AGE, SEX, SYMMETRY.

Age.

It was shown in a previous paper ('05 a) that my observations do not indicate any significant difference in the proportions of abnormality at different ages. The cases of incomplete division and incomplete fusion noted all seem to tend toward increasing the abnormality in *number* of scutes. Newmann ('06), after examination of nearly 500 specimens of *Graptemys*, including a number of embryos, finds that "abnormalities are no more common in one size than in another." He notes, however, some cases interpreted as stages in the squeezing off of scutes (cf., my specimens No. 50, p. 22, 23).

Sex.

The proportion of abnormality in the females of tables I to IV is noticeably greater than that in the males. Considering all the abnormalities of carapace and plastron, as defined on p. 12, above, 24 out of 71 males are abnormal, or 34 per cent, and 71 of 135 females, or 52.6 per cent. Of 37 the sex is not known. Of the entire 243, 109, or 45 per cent are abnormal. If, however, we consider only the possession of more or less than the typical number of scutes in the carapace, the proportion of abnormality is about 20 per cent.

Symmetry.

51 specimens show only symmetrical abnormalities.

44 specimens show only non-symmetrical abnormalities.

14 specimens show both kinds of abnormalities.

Thus, of the 109 abnormal turtles of tables I to IV, 51 are symmetrical, 58 unsymmetrical, in the respect that we have taken into consideration.

Before taking up the embryos and young of *Thalassochelys* it will be well to give a summary of the observations on *Malaclemmys*.

SUMMARY.

1. Observation of diamond-back terrapin in nature and in confinement reveals a marked degree of diversity in habit, disposi-

tion, and structure. Terrapins display much individuality in these respects.

2. The diversity in number and arrangement of the scutes accords with the general diversity. Of the first 243 specimens carefully observed, 20 per cent had either more or less than the typical number of scutes in the *carapace*. In all, 45 per cent showed such differences from the typical number, arrangement, and character of the scutes of carapace, plastron and inframarginal series, as to be classed for present purposes as "abnormal."

3. The "abnormalities" consist in: the possession of a greater or less number of scutes than 38 in the carapace, 2 in the inframarginal series, and 12 in the plastron; of instances of incomplete fusion or incomplete division of normal or abnormal scutes; of asymmetry in size and plan of scutes; of imbricateness of scutes; of the loose attachment of scutes to the bone beneath (one case).

4. *Asymmetry* manifests itself in various ways, and is at least as common in "abnormal" terrapins as symmetry.

5. *Females* show a much greater degree of diversity than *males*. This is true as regards both percentages of abnormal individuals and degree of abnormality in the average individual.

6. No evidence was noted of difference in the proportions of abnormality in *young* and *old* terrapins, but the data are inadequate for definite conclusion.

7. The most variable scute is the *inguinal*. Typically absent, it was present, on one or both sides, in 21 per cent of the 243 specimens. Its approximately symmetrical occurrence was noted in 13 per cent of the 243. Rarely, one or both *axillaries* were wanting. Sometimes they were reduced in size or asymmetrical.

8. The most variable scute of the carapace is the *nuchal*. Always present, it was sometimes paired, sometimes marked by a median groove.

9. Omitting the inframarginal series, the *plastron* is far less variable than the carapace. Diversity manifested itself by the presence of extra scutes in the plastral series and of inter-plastrals at the meeting-point of gulars and brachials, by partial fusion of scutes, and by asymmetry. Each abnormality is of rare occurrence.

10. Except in misshapen specimens, supernumerary *marginals* seem to occur only anterior or posterior to the region of the dorsal ribs. They are more common in the posterior region. A reduced number of marginals results from the lack of one or a pair of the posterior scutes. The alternating relation of scutes and plates is well preserved in several specimens.

11. Supernumerary *costals* may occur at the extreme anterior or posterior ends of the neural series, without disturbing the general plan of the series, or they may occur in such a way that the plan of the series is altered. The two series of costals may be asymmetrical even when the number of costal scutes is normal.

12. *Neural* scutes may be partially or completely divided by a median seam. This abnormality, though rare in the terrapins of North Carolina and Maryland, is very noticeable in those of Texas (Hay).

13. Asymmetrical scutes in the neural series are of not uncommon occurrence. There is observed an adaptation between asymmetrical neurals and asymmetrical costals that strongly suggests that the explanation of these scutes is to be sought in the *adjustment* of scutes consequent on some more primary asymmetry. I do not regard them as belonging in linear sequence and crowded out of position.

14. I believe that the asymmetrical neural scutes cannot be regarded, individually, as *atavisms*. Their adaptation to an *unsymmetrical* carapace seems too clear to permit of explaining them by reversion to any earlier symmetrical plan of scutes.

15. In the asymmetrical scutes we may find an illustration of the fact that we may best interpret a single variation not by regarding it as an isolated unit, but by viewing it in its relations to the associated structures with which it helps to form a more or less well co-ordinated whole.

PART II. THE SCUTES OF THALASSOCHELYS CARETTA (L.).

1. INTRODUCTION.

Material.

Only embryos and young were observed and these were obtained from eggs laid on the ocean beach near Beaufort. In studying the abnormalities it is important to know the conditions under which the embryos developed. The laying ground is inconveniently distant from the laboratory and the nests could be visited only by a sail and a walk on the beach that consumed the greater part of a day. The main object at the time was the collection of embryological material, and, as it was important to have the eggs conveniently accessible, it was necessary to remove them to artificial nests on the island on which the laboratory is situated. Another condition making it advisable to transplant the eggs was the difficulty of protecting the natural nests from depredation. Turtle eggs have a local value as food and are eagerly sought by fishermen. It was observed too that hogs root up the nests and destroy the eggs.

One nest was left undisturbed. A wire screen, placed over it and well under the sand, served to prevent the escape of the young turtles and to protect the nest from hogs. Traces of the nest were obscured as far as possible to prevent molestation by fishermen. The eggs hatched successfully (see Table VIII).

Most of the eggs were removed from the nests within two days after they were laid, usually on the following morning, and transferred in a bucket or box, in which they were covered with moist sand and seaweed. Usually care was taken to keep the eggs right side up. The eggs were then replanted either in artificial nests on the ground or in a sand-box or "incubator." The artificial nests in the ground were not successful. The soil, though chiefly sand, was of a different composition, and a higher temperature obtained than at the same depth on the beach. Other environmental conditions seemed unfavorable, and, in consequence, but a small proportion developed to a late stage. Unfortunately, the first observations indicated that nests in the ground would be more satisfactory than nests in an incubator,

so that most of the eggs were placed in the ground. Later it was found that a proper incubator would yield better results than the soil of the island.

The incubator used was very simple. It consisted of a box with four shelves, each holding 72 eggs. The shelves were large enough for each egg to be entirely surrounded by a small amount of sand. The light cushions of sand around and above the eggs served to maintain a comparatively uniform condition of humidity, while at the same time permitting the eggs to expand in size without crowding. This growth of the eggs, by the filling out and distension of the shell, commonly occurs to a greater or less extent during the development of the embryo. The sand was sprinkled with water as often as necessary. It was not necessary to apply artificial heat since the chief problem was to keep the temperature as low as it would ordinarily be at the depth of the natural nests. To obtain fairly uniform conditions of humidity and temperature, this box was placed within another box so much larger than the first that there was the space of 6 inches between the side walls (except on one side), the bottoms and tops, respectively, of the two boxes. The space between the two boxes was packed with moist sand. On the fourth side the inner box opened by a thick door containing a six-inch thickness of sand. Outside of this was the door to the outer box. Thus the inner chamber was well protected from such rapid changes of temperature or moisture as might take place outside. At the same time it could readily be opened at any time and one or more eggs removed without disturbance of the others. If the temperature seemed rising too high, moistening the outside of the box and the top layer of sand would, through evaporation, lower the temperature within a day; or, if necessary, the doors could be left open, when the evaporation would lower the temperature very quickly. In this way it was not difficult to keep a tolerably uniform temperature of 26° to 28° C.

The observations to be given below will at least suggest that the eggs of the loggerhead sea-turtle would lend themselves well to experimental study, by varying the conditions of incubation. During the past summer (1905), however, the experiments were made subservient to the obtaining of embryological material and it can-

not be said that this paper includes experimental observations of more than suggestive value. The observations given below were made on such of the embryos (and newborn) as were old enough for the scutes to be clearly distinguishable.

Before proceeding to the tables a word should be said as to the normal conditions of development.

Observations on Conditions of Development.

The loggerhead sea-turtle makes its nest in the region of Beaufort, at or near the base of the sand-dunes that line the beach at a short but varying distance from the water. The nest is subspherical, somewhat flattened on top, and packed with eggs usually to the number of 120-150. The top eggs are 12 to 15 inches below the surface, and, as the nest is 10 inches or more in diameter, the bottom eggs are 22-24 inches below the surface. At this depth, the bottom eggs may be below the level of the high tides, or as much as 4 feet above it, according to the elevation of the ground at the foot of the dunes.⁸

As the shell of the egg is soft and, in its new-laid condition, not completely filled, it displays a characteristic movable dent, like a rubber ball incompletely filled with air. In the course of development the contents increase in bulk and the shell becomes filled out and spherical: it may even be tightly distended. Agassiz says, "The older the egg the more distended does the shell appear." I have not found that the distension occurs invariably or to a uniform degree. The degree of distension varies with external conditions. Distension generally takes place, and it may occur to an extreme degree. With a large number of eggs massed together deep under the sand, the swelling of the eggs must cause great crowding and considerable interpressure. In one nest, for example, the eggs were so distended that upon a single puncture of a shell with a needle, a fine stream of fluid would squirt out a distance of several feet and the shell burst widely in the hand. Even though many of the eggs that failed to develop shrunk in size so as to be almost flattened

⁸See also my paper, '06, pp. 61 to 65.

against the sand, yet the pressure among those that developed was such that they lost their spherical shape and were somewhat flattened on the sides where they pressed against other eggs. Some of this flattening was lost before the photograph was taken ('06, Pl. XX., Fig. B). The possible influence of such a factor as this inter-pressure of eggs in the production of abnormalities of various kinds is not to be ignored. The indirect results of localized pressure on the developing embryo of other animals is well known, especially through such work as that of Spemann in the production of double-headed embryos and "cyclopean defects." It may not be a coincidence that two "cyclopean" embryos developed in the nest just referred to and that almost all of the turtles were abnormal in scutes, and some in still other respects.

Explanation of Tables.

There are four main tables (VI to IX). Table VI includes embryos from a single nest obtained in 1903. No further observations were made until 1905. Table VII includes the embryos and newborn from various artificial nests in the ground, and this table has several subdivisions (A-E) in order to keep separate the turtles from different original nests. In this way, the degree of diversity in turtles of the same brood may be noted. Table VIII is based on new-born turtles from a natural nest that was not disturbed. Finally, in Table IX are turtles which developed in the incubator, where crowding was provided against.

The tables have essentially the same form as those in the preceding part of the paper. The number of scutes in a series is indicated only where abnormal, or, if normal in number but abnormal in plan, the normal number is written in italics. The number of marginals, however, is always indicated since it cannot be said that either 12 or 13 is abnormal. Thirteen on each side, 12 on each side, or 12 on one side, 13 on the other—each of these plans is common. For brevity they are referred to as the 13-13 plan, 13-12 plan, 12-13 plan, or 12-12 plan, the number given first being in each case that of the left side. These plans may be seen, respectively, in Figs. 83, 58, 72, and 52.

The length is the full length of the carapace measured over the dorsal curvature and expressed in millimeters. The day of the embryo is indicated, when the embryo was taken from the egg alive, but the stage of development is perhaps best inferred from the carapace length, since the length of the incubation periods varies within wide limits (73, or less, to 90 days, or more). It was longer for eggs in the incubator than for those in the ground. "B" in the "day" column, indicates that the specimen was new-born.

2. OBSERVATIONS ON DIVERSITY.

The carapace differs from that of *Malaclemmys* in shape—it has a more aquatic form. It is broad in the anterior region, where the long stout swimming flippers are, and tapers to a comparatively narrow but rounded posterior end. The margin is indented over the anterior flippers, and sometimes slightly so over the posterior. As if in adaptation to the shape, with broad anterior end, the nuchal is very wide and the costal series terminates anteriorly in a small scute not represented in *Malaclemmys*, and others. There is often one more marginal in this region than is found in land and marsh turtles.

In Table VI are presented the observations on 34 embryos from the nest transplanted at the laboratory in 1903. Besides the fact of removal in the first instance, the conditions of development were otherwise abnormal. Only a small proportion developed successfully and most were removed from the nest during the period of incubation. Only one (No. 32) actually hatched.

Twelve of the 34 are abnormal in number or arrangement of scutes or in showing partial division of a scute. The abnormality frequently manifests itself in an asymmetrical plan of neural and costal scutes (Nos. 1, 23, 24, 26, 30, 31). In other cases the costal series of the two sides are unsymmetrical in number, without effect on the symmetry of the general plan of series (Nos. 6, 10, 21, 25). The proportions of these embryos with the several marginal plans referred to on p. 49, above, are interestingly uniform. Of the 29 specimens, in which the marginals could be counted with certainty, ten have the 13-13 plan, ten the 12-12 plan, and nine either 13-12 or

12-13. The most abnormal carapace is that of No. 26 (Fig. 63), with the large scute between neural and costal series, the small area in the mesial posterior region without a horny covering, and the minute scute that appears as if it were cut out of the left twelfth marginal. These three abnormalities are each unique among my observations.

The only striking abnormality noted, apart from scutes, was in No. 22, the fore feet of which were somewhat rudimentary.

Three small embryos of this nest are not included in the tables. One of these seems to have five neurals, a second six, and the third seven. The other scutes can not be distinguished with certainty.

Table VII, A, includes 21 embryos from two artificial nests, the eggs of which came originally from a single natural nest. In the table the first ten numbers are from one artificial nest. At the time of removal it was noted that the eggs were much distended, and, from the consequent crowding, more or less misshapen. One-half of the eggs started development, but not more than one-fourth were living on the 44th day. Two of the embryos were peculiarly abnormal. No. 36 shows an approach to the "cyclopean defect" (cf. 91, 92), but its scutes are normal. No. 35 (Figs. 66 and 67) besides having a harelip, was characterized by a remarkable foreshortening of the body; both heart and lungs are outside of the umbilical opening; the carapace, which measures 10 mm. in length and 17 in width, is almost regular and symmetrical, though its marked deficiency in length is accompanied by a corresponding reduction in the number of scutes in longitudinal series. As a transverse series of scutes may be said to consist of one neural, a pair of costals and two pairs of marginals, the shield is deficient by two complete transverse series, less two marginals on the right side. The inframarginal series are somewhat reduced, but the plastron has the full number of scutes, including an *intergular*, often wanting, and even one supernumerary scute posteriorly.

Three other specimens are abnormal in respect of scutes of the carapace, and one of these (No. 43) possessed minute "supramarginals."

The last 11 numbers in the table are from a different artificial nest. Most of these eggs developed to some extent, but only half

(11 out of 24) were living on the 49th day. The striking feature of this small group of embryos is that more than half displayed small scutes just above the marginals and always at the meeting point of three scutes (Figs. 73, 74). For convenience these are termed in the tables "supramarginals," though it is not intended thereby to imply any homology between these anomalous scutes and the typical supramarginals of *Macroclommys*. The prevailing plan of marginals is 13-13.

Table VII, B, is based on 14 embryos from a nest transplanted at the laboratory. Less than one-third of these eggs developed. Four of the 14 are abnormal, in having supernumerary marginals (three specimens), a symmetrical supernumerary neural (No. 60), or two scutes in the place of normal RC5 (No. 66). The marginal plan, 13-13, prevails. The large number of marginals (15-14) in No. 60 is noteworthy.

Table VII, C, includes 2 embryos and 7 new-born turtles from a nest transplanted at the laboratory. Three are abnormal, two of these having the costal series more or less asymmetrical and, in correlation with the costals, asymmetrical neural scutes. In one specimen (78) two neural scutes, in another (73) three are not completely separated from one another.

Table VII, D. This is a rather remarkable collection of embryos. Of the 22 specimens 18 are "abnormal," and these include several that are abnormal in scutes to a high degree.

Four are markedly deformed. No. 93 (Fig. 89) is asymmetrical and somewhat misshapen, and the number of marginals on the right side is unusually small. Two of these (Nos. 91 and 92) have an interesting deformity of the head. We are not concerned in this place with the details of anatomy, but the external characters of these specimens may be sketched briefly. The anterior mesial region of the face is reduced. The eyes are thus brought close together, or fused, and are enclosed by single upper and lower eyelids. The single nostril opens at the end of a short snout above the upper eyelid. In one specimen the snout points anteriorly. In the other it is, as it were, rolled back on the top of the head, the nostril appearing on the dorsal side of the posterior end of the flattened

backward pointing snout. In accord with the reduction of the parts just above it, the upper jaw is much shortened and flattened from the front so that it extends across from side to side in a more direct way than usual. The lower jaw, however, has about its usual form; so that, instead of being, as usual, enclosed within the upper jaw, it protrudes well beyond the upper. A somewhat similar embryo has already been alluded to (No. 36), Table VII, A). All three are further characterized by the very slight development of pigment.

The most remarkable deformity noted is that of No. 100 (Figs. 93 and 95). The lower jaw forms a pointed horizontal projection from the ventral part of the head, and on the dorsal aspect of this projection is a longitudinal slit representing the mouth. About halfway up the anterior aspect of the head is another pointed projection (snout?). There is no external evidence of eyes. The body is characterized by a reduction of its dorsal part. The carapace consists of two scutes with a smaller ovoid scute anterior to these (Fig. 95). On each side a bridge of one scute connects the carapace with the plastron, which possesses the full number of scutes. Posteriorly the plastron (Fig. 93) bends sharply dorsally in consequence of the reduction of the dorsal region. The dotted line in the figure indicates the region of the angle. Between the upper posterior end of the plastron and the posterior end of the carapace is the tail bearing the anus on its dorsal aspect. The heart, lungs, stomach and intestine lie external to the umbilical opening. The limbs are situated dorsally.

Among the smaller embryos with scutes undeveloped and, therefore, not included in the table was a fifth deformed embryo from the same nest. It needs only an allusion here. The body is reduced, and rounded, and the limbs appear rudimentary.

In view of the excessive proportion and degree of abnormality observed in this lot of embryos, the conditions of development should be described. The original lot of eggs was brought to the laboratory by a fisherman. According to his statement they were a mixed lot from two nests taken the preceding day. Some of them had dried somewhat and the lot was regarded as unpromising. However, they were placed in a single nest on the island made as usual in imita-

tion of a natural nest. The spot chosen proved to be rather more moist than usual. During development the eggs swelled to an unusual degree. As a result they were very much crowded and were misshapen (cf. remarks above, p. 48-49).

Many of these abnormalities are such as we would naturally attribute to the abnormal conditions of development, and the question naturally suggests itself: can the conditions of development be responsible for the remarkably large proportion of abnormalities of scutes in this nest?

The abnormalities take these forms chiefly:

1. Costals symmetrical in number, asymmetrical in plan, neurals asymmetrical (88, 97), or symmetrical (92).

2. Costals asymmetrical in number and plan, neurals asymmetrical (82, 90, 94).

3. Costals asymmetrical in number (through absence of normal small first costal), symmetrical in plan neurals symmetrical (80, 81, 87, 98, 99). Also, LC5 represented by two scutes (91).

No. 82 is further abnormal in that the first costal forms part of the margin (Fig. 84).

The nuchal is frequently paired or furrowed. The marginals are usually 12-12.

One specimen possesses supramarginals (No. 88, Fig. 85).

Table VII, E. The eggs were brought to me by a fisherman, who stated that they were a mixed lot from two nests taken two days before. They were replanted in the ground. The fourteen embryos and new-born make a comparatively normal lot. Though more than half (8) are abnormal, the variations are comparatively slight, consisting chiefly of paired nuchals, supernumerary costal posteriorly, supernumerary neural posteriorly, or incomplete division of N4 or 5, and slight asymmetry in the anterior region (104, 107). The marginal plan 12-12 is most frequent.

In Table VIII are presented the observations on 76 turtles from an undisturbed natural nest (see p. 46, above). The young turtles were found under the wire some days after hatching (88th day from the beginning of incubation). Only one unhatched egg remained in the nest.

As there were very few abnormal turtles, and since all are of approximately the same age, the table may conveniently be abbreviated. First the abnormal turtles are listed, and then the normal turtles in several classes according to the plan of the marginals.

The abnormalities are: C5 represented by 2 scutes (4 specimens), nuchal paired (119), N5 incompletely divided transversely (120), and, supernumerary marginal (121).

All of the common marginal plans occur, but 13-13 largely predominates (40 specimens).

As the nest was never disturbed during the period of incubation (except at the start) it cannot be stated whether or not there was much swelling of eggs with consequent pressure between them. This undisturbed natural nest yielded a far greater proportion of normal turtles than any nest transplanted into the ground at the laboratory.

Table IX. On account of the possibility of the pressure in natural and artificial nests having some effect on the method of growth of the scutes it was desired to remove some eggs from such conditions. Therefore, a number of eggs from two or three nests were placed on the shelves of the incubating box described above. The eggs were surrounded and covered by a very small amount of moist sand, but not sufficient to offer any considerable resistance to the expansion of the egg in any direction. On account of the poor success of the eggs transplanted into the ground, the incubator was frequently drawn on for embryological material, especially to fill the gaps in the earlier stages. Table IX, therefore, includes only 18 embryos—all from a single original nest. The number is entirely inadequate for conclusion, but it was interesting to find that only a single specimen was abnormal (by the possession of a 6th neural—cf., Fig. 79). The marginals display exceptional uniformity. In the three youngest specimens they were not distinct, in one the plan is 13-12, but in *all* the others the plan is 12-12. It is possible that the eggs from this original nest would have developed with as much uniformity under other conditions.

The table can conveniently be abbreviated.

TABLE VI.

THIRTY-THREE EMBRYOS AND ONE NEWBORN.

Eggs from one original nest transferred to one artificial nest in the ground.

Serial Number.	Length of Carapace in Millimeters.	SCUTES.								REMARKS.	Figures.
		Nuchal.	Neurals.	Cos-tals.		Margi-nals.					
				Left.	Right.	Left.	Right.				
1	23	1	5	5	5	?	?	(Normal).			
2	24					?	?	(Normal).			
3	25		x			13	13	N5 partially divided transversely.			
4	26					?	?	(Normal).			
5	26					?	?	(Normal).			
6	26	x		4		12	13	Marginal series encroaching on nuchal.	57		
7	27					?	?	(Normal).			
8	27					12	12	(Normal).			
9	27					13	13	Normal.			
10	28			6	4	12	12		52		
11	29					12	12	Normal.			
12	29					12	13	Normal.			
13	30					13	12	Normal.			
14	30			6		13	13		56		
15	30		x			13	12	Normal except that LC1 is rather large at expense of LC2. LM2 very small.	58		
16	31					12	12	Normal.			
17	31		x			12	12	N5 divided obliquely; seam distinct on R side, faint on L posteriorly.	55		
18	31					13	13	Normal.			
19	31					12	13	Normal except R marginals. Cf. figure.	59		
20	31					13	12	Normal.			
21	32			4		13	12	Supn'y marg. on left side posteriorly.			
22	32					12	12	Normal. (Fore-feet reduced).			
23	33		7		6	13	13		61		
24	34		8			13	12		62		
25	35			x		13	13	L costal series normal except for minute scute at posterior end.	60		
26	36	pr	6	x	x	12	12	Difficult to diagnose; cf. figure.			
27	39	f	x			13	13	Faint furrow on N1 and N2, extending into spine; abrupt back side of spines furrowed.	63		
28	39					12	12	Normal.			
29	40					12	12	Normal.			
30	44	pr	7	4	6	13	13	Faint furrow on N1 and N2 and, more distinctly, on N3, Supn'y marginal posteriorly on left side.	64		
31	45		6	6		13	13				
32	46					13	13	Normal. Nuchal and N1 and N2 show very faint traces of furrow. (Hatched.)	65		
33	48					13	12	Normal.			
34	52					13	13	Normal.			

TABLE VII.

EMBRYOS AND NEWBORN—FROM ARTIFICIAL NESTS IN THE GROUND.

A. 21 Embryos—Originally from One Natural Nest.

Eggs transferred to two artificial nests in the ground. The first 10 embryos below (Nos. 35-44) came from one of these nests, the remainder from the other.

Serial Number.	Length of Carapace.	Day.	SCUTES.						REMARKS.	Figures.
			Nuchal.	Neurals.	Costals.	Marginals.				
					Left.	Right.	Left.	Right.		
35	10	44th		3	3	3	8	10	Remarkable foreshortening of body; compare figures. Width 17 mm. (Head with hare lip defect.) (Plastron with one supn'y scute.)	66 67
36	19	"					12	12	Scutes normal. ("Cyclopean defect" of head.)	
37	19	"		7		5	12	12	RC3 much reduced.	71
38	23	"					13	13	Normal.	
39	24	"					13	13	Normal.	
40	24	"					13	13	Normal.	
41	25	"					13	12	Normal.	
42	26	"				5	13	13	RC5 incompletely divided.	69
43	26	"		7		5	12	13	RC4 somewhat reduced, so that RC5 occupies a position more anterior than normally—cf. relation to marginals. Minute supramarginals observable with lens.	72
44	28	"					13	13	Normal.	
45	36	49th		6		7	13	13	2 scutes occupying place of RC5; also 1 supn'y scute posteriorly.	70
46	37	"					13	13	Normal.	
47	40	"					13	13	1 supramarginal, left side, between C2 and M8.	
48	41	"					13	12	3 supramarginals on each side; one is minute.	73 74
49	41	"					13	13	Normal.	
50	41	"					14	13	Supramarginal between C2, C3, and M8, right side.	
51	41	"					13	13	Minute supramarginal between C3, C4, and M8, left side.	
52	42	"					13	13	Normal.	
53	43	"					13	13	Small supramarginal, between C3, C4, and M8, left side.	
54	48	"		5			13	13	N5 is completely divided transversely.	75
55	50	"					13	13	2 supramarginals on R side, 3 on L. Fig. would apply to R side, with smallest scute omitted; applies to L side.	

B. 14 Embryos.

Originally from one natural nest.

56	35	?					13	13	Normal	
57	38	45th					12	13	Normal.	
58	41	"					13	13	Normal.	
59	41	"					12	13	Supn'y marginal posteriorly, right side. Malformation of posterior margin right side.	80
60	41	"		6			15	14	Regular scute following N4. Marginals with 14-13 plan anteriorly but with supn'y scutes posteriorly, each side.	79
61	42	"					13	12	Normal.	
62	43	"					12	13	Normal.	
63	43	"					13	13	Normal.	
64	44	"					13	13	Normal.	
65	44	"					13	13	Normal.	
66	45	"				6	13	13	RC5 represented by 2 scutes.	68
67	46	48th	x				13	13	Normal, except that nuchal is notched and shows slight median furrow.	
68	46	"					13	13	Normal.	
69	48	"		6	6		14	14	LM2 and LM4 very much reduced.	76

TABLE VII.—(Continued.)

C. 2 Embryos and 7 Newborn.

Originally from one natural nest.

Serial Number.	Length of Carapace.	Day.	SCUTES.						REMARKS.	Figures.
			Nuchal.	Neurals.	Cos- tals.	Marginals.				
						Left. Right.	Left. Right.			
70	53	63d	x			13	12	<i>Normal.</i> Trace of median furrow on nuchal.		
71	53	"			6	13	13	RC5 represented by 2 scutes. RM2 much reduced.	83	
72	49	B				12	12	<i>Normal.</i>		
73	49	"		x		12	12	Neural series of 7 elements, but 3 of these (N4, 5 and 6) are incompletely separated from one another.	81	
74	51	"				12	12	<i>Normal.</i>		
75	52	"				13	12	<i>Normal.</i>		
76	53	"				13	12	<i>Normal.</i>		
77	53	"				12	12	<i>Normal.</i>		
78	55	"	x	x	x	13	13	Neural series of 8 elements, but N3 and N4 are not completely separated mesially. Nuchal with distinct furrow to left of median line, anteriorly. LC1 wanting; LC5 represented by 2 scutes.	82	

D. 22 Embryos and Newborn.

Eggs originally from 2 natural nests—but transplanted into one artificial nest.

79	20	?				12	?	12	(Normal.) L marginals not thoroughly clear anteriorly.		
80	29	54th	pr		5	5	6	12	12	Supn'y costal on each side, but LC1 wanting. No supn'y neural, but N4 with beginning (?) division on each side so as to give usual adjustment.	78
81	32	"			6	5	6	13	13	Symmetry of LC1 and 2 with RC2 and 3 suggests that there is a supn'y costal on each side while LC1 is wanting.	77
82	34	"	x			12	13	12	13	Very abnormal: see text, p. 54.	84
83	35	"	x		6	5	4	12	12	Normal. Slight median furrow on nuchal posteriorly.	
84	35	"	pr			12	12	12	12		
85	38	?	pr			12	12	12	12		
86	40	54th				12	12	12	12	Normal.	
87	41	"				12	12	12	12	RC1 merged in 2.	
88	41	?	x			4	12	13	13	Nuchal divided anteriorly. N6 showing trace of seam, distinct on left posteriorly. 5 "supramarginals", 4 of which are very minute.	85
89	44	54th	f		6	12	12	12	12		
90	51	"				6	12	12	12	Much of the distortion observable in the figure is due to contraction in the preservative.	86
91	47	73d	pr		7	12	12	12	12	LC5 represented by 2 scutes. "Cyclopean".	88
92	48	"	x			6	12	12	12	Scutes abnormal anteriorly. "Cyclopean".	87
93	52	"	x	5		12	10	12	10	Somewhat asymmetrical and misshapen. Nuchal with median seam anteriorly, continued posteriorly by a furrow.	89

TABLE VII.—(Continued.)

Serial Number.	Length of Carapace.	Day.	SCUTES.						Figures.	
			Nuchal.	Neurals.	Cos- tals.	Marginals.		REMARKS.		
						Left. Right.	Left. Right.			
94	53	"	pr	8	6	12	13	N2, 3 and 4 incompletely separated mesially.	90	
95	54	"				12	12			
96	52	B				12	12			
97	53	B		8	6	6	13	13	<i>Normal.</i> Supn'y scute in each costal series. Probably LC6 is supn'y, since the costals anterior to it have the usual relations to marginals. On the right side the scutes posterior to RC3 have the usual relations to marginals of C2-5; hence RC2, or 3 is probably supn'y (contrast with Nos. 80 or 92).	91
98	53	B				4	12	13	RC1 wanting, LC1 reduced. Supn'y marginal-posteriorly, right side.	92
99	54	B				4	12	12	Like the above, except for the supn'y M.	
100	6	54th							Remarkable carapace of 3 scutes. v. text, p. 53. Plastron with normal number of scutes.	93 95

E. 14 Embryos and Newborn.

From one artificial nest. Eggs from two natural nests mixed.

101	31	38th				12	12	<i>Normal.</i>		
102	33	"	x			12	12	Nuchal divided symmetrically by a seam anteriorly, continued as a furrow posteriorly.	94	
103	35	"		5		13	13	N4 partly divided transversely.	96	
104	39	"	x	x	x	13	13	Asymmetry of nuchal, first neural, first costal and first marginals.	98	
105	40	47th				12	12	<i>Normal.</i>		
106	41	"	pr			12	12			
107	42	"	pr			13	13	Nuchal seam oblique.	97	
108	46	B	x			12	12	<i>Normal.</i> Trace of furrow on nuchal.		
109	47	B		6		12	12		99	
110	48	B				13	12	<i>Normal.</i>		
111	49	B				12	12	<i>Normal.</i>		
112	49	B	pr			14	13		103	
113	50	B				12	13	<i>Normal.</i>		
114	51	B		5	6	6	12	12	N5 partly divided. LC5 represented by 2 scutes. Supn'y costal on R side.	101

TABLE VIII.

76 NEWBORN TURTLES FROM A NATURAL NEST.

Serial Number.	Day.	SCUTES.						Figures.	
		Nuchal.	Neurals.	Costals.		Marginals.			REMARKS.
				Left.	Right.	Left.	Right.		
115	B			6		13	13	LC5 represented by 2 scutes.	
116	"			6		13	13	LC5 represented by 2 scutes.	
117	"			6		12	12	LC5 represented by 2 scutes.	
118	"				6	13	13	RC5 represented by 2 scutes.	
119	"	pr				12	12		
120	"		5			13	13	N5 divided on R side	102
121	"					13	14		
122	"					13	13	36 normal turtles.	
157	"					13	12	8 normal turtles.	
158	"					12	13	13 normal turtles.	
165	"					12	12	12 normal turtles.	
166	"								
178	"								
179	"								
190	"								

TABLE IX.
EIGHTEEN EMBRYOS AND NEWBORN.
Transplanted from a single natural nest to an incubator.

Serial Number.	Length of Carapace,	Day.	SCUTES.						REMARKS.
			Nuchal.	Neurals.	Cos- tals.	Marginals.			
						Left.	Right.		
						Left.	Right.		
191 }	12	32d	?			?	?	3 embryos <i>normal</i> as far as observable.	
193 }	12	34th				12	12	<i>Normal</i> .	
194 }	12	34th				12	12	<i>Normal</i> .	
195 }	13	35th				12	12	Supn'y neural posterior.	
196 }	17	34th	6			12	12	<i>Normal</i> embs. Car. of 196 and 197: 19 mm.	
197 }	x	34th					12	Car. of 198 and 199: 20 mm.	
200 }									
201 }	47	60th				12	12	<i>Normal</i> .	
202 }		B				12	12	6 <i>Normal</i> turtles.	
207 }									
208 }		B				13	12	<i>Normal</i> .	

3. REVIEW OF OBSERVATIONS.

Marginals.

In strong contradistinction to most turtles there is no definite number of marginals that can be considered normal. In the 12-plan (see above, p. 49), the first costal is in contact with only two marginals (M1 and M2), the second with four (M's 2, 3, 4 and 5)—Fig. 74. In the 13-plan, the first costal is in contact with three marginals, the second with M's 3, 4, 5 and 6. The differences between the two is therefore, the presence in the one case, the absence in the others, of a scute between M1 and the marginal opposite the seam posterior to C1 (marked *Mx* in Figs. 76 and 79). This scute varies in size from a very minute scute entirely surrounded by the scutes preceding and following it (Fig. 76) to a size as large as the others, Fig. 79 right. Compare Fig. 79 left, Fig. 76 right, and Fig. 83, left and right. Sometimes, with the 12-plan anteriorly, there occurs a posterior scute, making the number really 13. This is spoken of as the 12-plan with a supernumerary scute posteriorly.

Sometimes an extra marginal appears in the region of C2. This scute, *My*, Fig. 76, leads to a 14-plan if *Mx* is also present. Again, a scute, *Mz*, may intervene between the most posterior marginal and the marginal opposite the seam posterior to normal C5. In this event the series contains 13, 14, or 15 scutes, according as the 12-plan, 13-plan, or 14-plan prevails anteriorly. Compare Fig. 92 right—13 scutes (*Mz*), Fig. 79, right—14 scutes (*Mx*, *Mz*), Fig. 79, left—15 scutes (*Mx*, *My*, *Mz*).

As to the relative frequency of the common marginal plans, 12-12 and 13-13 occur approximately in equal proportions, 12-13 and 13-12 occur each about one-third as often as either of the symmetrical plans. The scutes *My* and *Mz* are of rare occurrence. Supernumerary scutes at other places were not observed. The stippled area of M10, Fig. 84, represents an infolded area. The posterior limb is folded over the carapace in this region, and the slight malformity of the margin noted in this region in this and other specimens (Figs. 80 and 76) undoubtedly results from undue pressure of the limb against the margin, and this suggests the same explanation for the malformed margins of *Malaclemmys* (Figs. 32, 37, 39, 40).

Such crude direct effects of pressure are not to be confused with the possible indirect adaptive results suggested above (p. 49).

Less than 12 marginals were observed only in malformed specimens. In No. 35 (Fig. 66), with marginals 8-10, the right marginal series shows less reduction than any other series of the carapace. In No. 93 (Fig. 89) the marginals are 12-10.

Supramarginals.

Small scutes, just above the margin and at the meeting-point of three scutes, are noted only in No. 88 of Table VII D (Fig. 85), and in several embryos of Table VII, A (Nos. 43, 47, 48, 50, 51, 53 and 55, Figs. 73 and 74). The costals do not seem quite to meet the marginals in early stages, and if the presence of scutes between costals and marginals be attributed hypothetically to arrest of development, these observations may lend some support to Newmann's hypothesis as to the number of primary series of scutes in the carapace. But would not such an assumption as to the significance of supramarginals place them in a distinct class from other supernumerary scutes for which arrest of development is not to be hypothesized?

Nuchal.

As was the case in *Malaclemmys*, so here the nuchal is frequently found in paired condition (eleven instances, Fig. 103, etc.), or marked by a median furrow, which may be quite distinct (three instances) or very faint (four instances). In one case an anterior seam was continued posteriorly by a furrow (No. 93, Fig. 89).* The furrow is incomplete in No. 78, Fig. 82, and the seam incomplete in 88, Fig. 85. The division is usually symmetrical but not always so.

Costals.

Each costal series consists of five scutes, the most anterior being very small, and having no analogous element in *Malaclemmys*. It may be noted that, when there are twelve marginals, the first two costals are in contact with the first five marginals. In *Malaclemmys*, which has, typically, twelve marginals, the first costal is in contact

*Also No. 102, Fig. 94.

with the second to fifth marginals, the narrowness of the nuchal bringing the first marginal into a position anterior to the first neural. Where an anterior supernumerary costal occurs in *Malaclemmys*, the relation of the first two costals to the marginal corresponds to that in *Thalassochelys*, Fig. 9, left. Sometimes the small first costal of *Thalassochelys* is wanting (seven instances) and then the condition approximates that of *Malaclemmys* (cf. Figs. 57 and 92). Symmetry in this abnormality was never noted; in fact, in two of the seven specimens a supernumerary scute was present on the opposite side, Figs. 52 and 64. This suggests that the absence of this scute is attributable to some primary asymmetry rather than to reversion.

Another not infrequent abnormality of costals consists in the presence of two scutes in the place of C5. The two scutes, together, have practically the usual relations of C5 to marginals on the one side and to neurals on the other. Cf. Figs. 70, 83, right, and 56, 82, 88, left. Nos. 10, 66, 115, 116, 117, 118, 114 left (Figs. 52, 101) have the same abnormality. Contrast with these the posterior supernumerary scute of No. 69, Fig. 76, and 114, right, Fig. 101, also the incomplete division of LC5 in No. 42 (Fig. 69).

The abnormalities of costals so far mentioned, while manifesting asymmetry so far as the numbers of scutes on the two sides goes, leave the two series symmetrical in general plan. But the plan is disarranged in such specimens as Nos. 94 (Fig. 90) and 97 (Fig. 91) and, as we shall see below, the number of extra neurals occurring in association with such abnormalities of costals depends on the extent of the asymmetry.

Asymmetry may occur without supernumerary costals, Figs. 71, 72, etc.). On the other hand, supernumerary costals may occur symmetrically; Fig. 78 illustrates this, if it be assumed, as seems apparent, that LC1 is wanting while the next to last costal of each side is supernumerary.

Neurals.

Paired neurals or neurals incompletely divided in the median line were not found, but a slight median furrow was sometimes observed.

A very symmetrical supernumerary neural sometimes appears in sea-turtles just posterior to N4. This scute is almost perfectly

rectangular (Fig. 79). Such a shield was found in two of four shells of *Colpochelys kempii*, and in three of thirty-one specimens of *Chelone mydas*. In several cases there is a horizontal seam confined to one side, which, if complete, would isolate such a scute. (Nos. 3, 54, 103, 114, 120, Figs. 75, 96, 101 and 102.) Hence the seam which cuts off this scute from N5 occurs more frequently on one side than on both. The partial independence in variation shown by the two sides is nicely illustrated in this case, as in many others.

A seam may start from the usual point of origin of the seam bounding the rectangular scute posteriorly, but bend posteriorly to meet the last costal distally or the marginals (Nos. 37, 73, 109, 196). Cf. Figs. 71, 99, and 81. A short seam completed by a furrow is shown in Figs. 55 and 85.

In Fig. 96 N4 is partly divided by a seam on the right side which is completed on the left by a furrow.

Adjustment of Neurals and Costals.

No. 81 (Fig. 77) illustrates well this adjustment: neurals and costals in alternating relation. In this specimen I infer that LC1 is wanting and that a pair of supernumerary scutes is present; but, disregarding this inference, there are, on each side, five costals in contact with neurals posterior to N1, while in the normal carapace there are only four. As the costals are nearly symmetrical from this point posteriorly, a single nearly symmetrical extra neural serves to maintain the usual alternating relation. In 31 (Fig. 65) the supernumerary costal is on the left side alone, and here again we find on each side the usual alternating relation of neurals and costals. Counting down the left side there are six neurals, counting down the right side there are five. The supernumerary neural is not absolutely restricted to the left side nor unmodified on that side, but tapers to a point. It seems that in *Thalassochelys*, the asymmetrical scutes are not in general as much restricted to one side as in *Malaclemmys* and *Graptemyx*. Shells, such as No. 94 (Fig. 90) and 97 (Fig. 91) are very suggestive of the types noted in the first part of this paper (p. 34, above), but more commonly the asymmetrical elements are of the type of those of 43 (Fig. 72) and 90 (Fig. 86),—

comparatively broad on both sides but widest on the side where they are in proper alternation with the costals. The subject has been so fully discussed in a previous section that I need only refer to the figures: Figs. 61, 62, 64, 72, 70, 84, 85, 90, 91, 100, and a few others that need special discussion.

In No. 80 (Fig. 78) there is the normal number of neurals with, evidently, a pair of supernumerary costals; N4 is a large scute where we would expect two scutes to complete the alternation; but we find on each side the beginning of division opposite the apices of costals.

In No. 210 (Fig. 104) the incomplete seam on the left side is to be noted.

In 73 (Fig. 81) the correlation is complete except in so far as two of the seams are incomplete mesially.

No. 78 (Fig. 82) presents an unexpected scute in the oblique fourth neural. The incompleteness, mesially, of its anterior seam suggests that this scute was still more abnormal at an earlier stage. But if this carapace is to be in harmony with the others, we would expect the development of a seam from the point *x* extending toward the left end of the third neural or toward the second costal.*

No. 94 (Fig. 90) has already been referred to; but it is to be noted that two of the seams are completed in the mesial region only by furrows.

No. 92 presents a clear case of "mal-adjustment" (Fig. 87). N2 is an exceptionally large scute and there are not even the beginnings of seams from the apices of the third costals. It is not surprising, however, that this turtle should fail to manifest the usual laws of development in scutes or in any other organs. Its "cyclopean defect" alone gives it a hopeless deformity.

"Incomplete Division."

It may be said that it is "begging the question" to assume that the incomplete seams represent *division* rather than *fusion*. Against the latter explanation it may be said that such seams are always in the peripheral or growing region of the scutes, and that, where

*The letter is omitted in the plate. The point *x* is on the fourth neural seam near the apex of the third right costal.

they shade off into furrows, the furrow is mesial, and the seam most distinct at the periphery. Further, in *Malaclemmys*, as has already been shown ('05a, p. 14 ff.), the successive concentric rings of growth give a sure means of determining that the incomplete seams noted in that species are of subsequent development. This seems sufficient to make "partial division" acceptable. It may be added that the incomplete seams would be quite inexplicable on the supposition of fusion. Gadow's hypothesis may presuppose fusion of scutes, but these cases could not fall in line with his hypothesis.⁹ We would have scutes fusing that were not supposed by the hypothesis to fuse (cf. Figs. 81, 82, 91). On the other hand, as expressions of laws of growth that are not complied with until these seams appear, the late appearance of the seams is quite explicable. It is evident that, instead of suggesting arrest of development as the explanation of supernumerary scutes, they would point in a contrary direction. If they have a significance as to ontogenetic development they point to perfection of adjustment as opposed to perfection of number of elements. See also Fig. 104 (specimen 210, not listed).

Finally, whether the blind seams represent division in process, as suggested, or merely broken seams in stable condition, their positions and their peculiar association with other abnormalities are too suggestive to go unremarked.

We speak of supernumerary *scutes*, although it may be more a matter of *seams* than of scutes. We have to do merely with the subdivision by seams of a given horny area. What determines the plan of the seams, to what extent it is dependent on vasculature or on the relations to the bones and other organs beneath, we do not know, but it is quite conceivable that the laws of growth and of adaptation to diverse environmental conditions are adequate to account for the diverse plans of scutes. The evidence points very directly to the conclusion that the development of asymmetrical seams in the neural region takes place in accord with laws of growth as distinguished from laws of heredity, and this may well be the case with other abnormalities.

⁹Gadow's figures are not reviewed here, since, though showing a high degree of multiplication of scutes in the several series, the supernumerary scutes are hardly comparable to those dealt with in this section; supernumerary scutes

Salient features of the observations on *Thalassochelys*:

(1) The very high proportion of abnormality in these turtles, which developed chiefly under abnormal conditions.

(2) The general unsymmetrical aspect of the abnormalities, the marginal, Mx, being an exception, since it occurs on both sides more frequently than on one side alone.

(3) The occurrence of small "supramarginals"—not previously recorded as an abnormality; these are always at the meeting point of three other scutes.

(4) The development of an embryo with only 3 scutes in each dorsal series (Fig. 66), and another *with 3 scutes* forming the entire carapace.

(5) The appearance of a number of "monstrosities"—"cyclopean" embryos, etc.; and the association of a high proportion of abnormality of scutes with the occurrence of these monstrosities.

Supernumerary scutes occur in the neural and costal series with much irregularity and without symmetry. The only symmetrical recurring scute in either series is the rectangular scute posterior to N4. At least two abnormalities in the costal series show a regularity in their recurrence: these are—the absence of the small C1, and the presence of two scutes in the place of C5; but neither of these abnormalities appeared on both sides and symmetrically.

PART III. SIGNIFICANCE OF THE ABNORMALITIES.

Introduction.

The specimens of *Thalassochelys* observed display an even greater degree of diversity in number and arrangement of scutes than did those of *Malaclemmys*. While Newmann found that one-tenth (48) of 476 specimens of *Graptemys* had supernumerary scutes in the carapace, and only about one-twentieth of 188 specimens of *Chrysemys*, about one-fifth of the first 243 specimens of *Malaclemmys* observed had more or less than the typical number of scutes. But

are intercalated, generally in association with intercalated costals, sometimes independently, but not with marked asymmetry. In fact, the only abnormalities in my specimens that resemble those of his are the presence of 2 scutes in place of C5, and the interposition of a small neural posterior to N5.

in 208 specimens of *Thalassochelys*, almost one-third were abnormal. The diversity in *Thalassochelys* is even greater than this proportion indicates, for, in estimating that proportion of abnormality, both twelve and thirteen marginals were considered as normal. The variable M2 is absent almost exactly as often as it is present and in one-fourth of the total number of specimens it is absent on one side while present on the other. It seems remarkable that there should be such diversity in forms that have been so little modified through several geological ages. *Thalassochelys* is at least as old as Eocene times, and turtles of the Upper Jura have essentially the same number and arrangement of scutes as have modern turtles. From one point of view the arrangement of scutes is exceptionally plastic or variable, while from another, the paleontological point of view, it is exceptionally persistent and fixed.

It would be interesting to know the explanation of the "abnormalities," such a large proportion of which show asymmetry, but the data that we have in hand are, comparatively, very scant. It is advisable, however, to consider the explanation advanced hitherto (atavism) and other possible explanations in the light of the data in hand.

External Conditions.

We have not sufficient evidence as to the influence of the environmental conditions of the eggs during development in the production of abnormalities of scutes. A large proportion of abnormalities was found in each of the nests transplanted into the ground at the laboratory, all of which were under more or less unfavorable conditions. The nest which showed by far the largest proportion of abnormal specimens was one in which very great pressure from the distension of the eggs was noted. The smallest per cent of abnormality yielded by any nest in the ground was found in the turtles from eggs left undisturbed to hatch under natural conditions; but the most normal lot of turtles of all was that obtained from eggs which developed in the "incubator," with the element of pressure eliminated. The series is inadequate for positive conclusions, however, as the number of embryos is too small, but it suggests the importance of further experiments.

Inheritance from Immediate Ancestors.

The diversity in some of the lots of turtles, each of which groups came from one original nest (Tables VI and VII, A, B, and C) certainly does not suggest that the abnormalities of the parents had a great influence on the abnormalities of the young, but on this point, again, the data are inadequate.

Atavism.

It has been seen that the prevailing interpretation of the abnormal scutes is that they are atavisms; "reminiscences of earlier, phylogenetic conditions" (Gadow, '05, p. 638); "examples of systematic atavism in the sense of de Vries" (Newmann, '06, p. 69). In studying this diversity of scutes, then, one is confronted at the outset by these questions: are all of the abnormalities to be regarded as atavisms? and, if not all, which anomalies are due to reversion? Comprehensive use of the conception of "systematic atavism," as applied to these variations, has been made for morphological purposes, and as the observations given in this paper might be taken some to confirm, some to modify, others to negative such morphological views, I consider it necessary to inquire with some fulness regarding the basis of the atavistic interpretation of supernumerary scutes.

It has already been made clear that asymmetrical neurals are not to be regarded as instances of reversion. Further, from a glance at such figures as Figs. 63, 66, and 95, we infer that some others of the abnormalities are surely not referable directly to atavism. But, are most of the supernumerary scutes to be explained by reversion? and, *by what criterion shall it be decided if a given scute is atavistic or coenogenetic in character?*

By *atavism* we understand ordinarily the reappearance of a character, not manifest in the immediate ancestors, but typical of some remote ancestral form. It is assumed that this character, though disappearing from view, has never been actually lost, but, having assumed a latent condition, has been transmitted from generation to generation until finally, on the proper occasion, it reasserts itself. Atavism is, therefore, much more than a descriptive term referring

to the resemblance of a new to an old character; it is a positive assumption of the unbroken continuity of the old quality in latent condition through succeeding generations and its final reappearance as a variation.

The need for this theory of reversion has been felt as an explanation of the observed fact that the offspring often manifests some character not possessed by its immediate parents, but peculiar to its grandparents or to some more remote ancestors. Especially in the latter case do we, in Darwin's words, "feel a just degree of astonishment," and, whether the resemblance is to a near or to a more remote ancestor, does there seem a need for the theory of latent characters and reversion. It would seem, however, that the theory was one to be invoked only in cases where there is strong reason to believe that the resemblance is not superficial or accidental, but so vital and unmistakable as to be explicable only as a direct inheritance. Yet the theory of reversion has been overworked to the point of being applied to cases of the most superficial resemblance, even to variations that bear resemblance only to a purely constructive ancestor, the hypothetical existence of which is based largely on the arbitrary assumption that the anomaly in question is an atavism.

The subject of polydactylism in higher vertebrates not only offers an excellent illustration of the wholesale use of the theory to explain all kinds of anomaly, but it is one which has been so much longer and more thoroughly studied in its various aspects (anatomy, heredity, etc.) than has the subject of supernumerary scutes, that we may be allowed to draw some lessons of caution from its history, if we do not seem to imply that the same principles must apply to scutes as to digits.

Darwin himself, "with much hesitation," attributed polydactylism in man to reversion, but soon retracted ('76, p. 459), with the explanation that he had been misled by the statements of observers. The bifid rays of Selachians, and "constructive" 7-toed ancestral mammals, have been called up to account for modern polydactylism (Albrecht, Bardeleben, etc.). Other writers, as Gegenbaur, and, especially, Bateson and Prentiss have put the matter in a better light. Certainly the following simple principles, self-suggesting, would seem demonstrated in regard to polydactylism.

1. External resemblance is not ground for the assumption of reversion (since the presence of two digits in the horse is sometimes due perhaps to the development of the vestigial second digit, or, in other cases, clearly to the duplication of digit three. (Prentiss, '03, p. 299).

2. Recurrence of a similar abnormality in numerous individuals of the same or different species is not ground for the assumption of reversion. (Cf. duplication of hallux or pollex in man, cat, dog and fowl. Bateson, Prentiss, etc.)

3. Where extra elements occur which are, presumably, of vestigial origin and possibly attributable to reversion, the atavism may be by no means true to the ancestral condition reverted to; for Prentiss ('03, p. 291) finds that, in a large number of cases, the supernumerary *vestigial* digit appears in a condition of partial or complete duplication—that is to say, in a condition directly misleading if used for inference as to ancestral form.

4. Supernumerary elements have a negligible value as basis for phylogenetic hypothesis.

Without regard to polydactyly, the above considerations suggest themselves *a priori* against the attribution of definite morphological significance to supernumerary scutes. I refer to polydactyly because these *a priori* objections seem to gain weight from their demonstrability in another field of variation.

In regard to scutes the following points may be noted:

1. We have no evidence as to the value of external resemblances—as to whether the same appearance might not be due in one individual to one cause, in another to a different cause.

2. The assumption that anomalies of scutes are atavisms rests on the recurrence of certain more or less characteristic scutes in different individuals of the same species, and in different species, and the correspondence of such scutes in a few instances to normal scutes of still other species. But recurrence of certain very definite anomalies in the same or in different species is often noted in cases where atavism would not be suggested. Thus the cyclopean defect occurs in man, and in an essentially similar form in amphibia (Spemann, '04). I have had apparently the same sort of defect to

appear in three embryos of the loggerhead turtle, taken from artificial nests, and the resemblance to the same abnormality in man and in Triton is striking. Here is the same abnormality occurring in different and widely removed species, and with remarkable definitions of form.

The matter of recurrence need present little difficulty. If the organization of one turtle is much the same as that of another of the present time or of a considerable period of past time (and observations so indicate), I do not know why turtles may not be subject to similar anomalies; nor why there may not occur now the same variations that once, in connection with others, characterized the ancestors of a diverging species; nor why, if any of the variations now occurring should characterize a future subspecies or species, they might not continue to occur in other turtles without acquiring a new significance.

3. The use of the supposed atavisms as morphological data implies not only the transmission of the primitive characters in latent condition from generation to generation since remote geological ages, but also that they are now seen practically in pure form and unmixed with any appreciable number of new inheritable variations, occurring first during these ages since the primitive characters became latent. The ground for such an assumption is not apparent.

4. From the phylogenetic point of view, how far back must the atavism of scutes point? The whole matter of the phylogeny of turtles is obscure, but, from paleontological data, it is evident that the carapace of Thecophorous turtles acquired at quite a remote period very nearly the present form as regards arrangement of scutes and plates. Existing genera may be traced back to Eocene (*Thalassochelys*) and Upper Cretaceous periods (*Chelone*). More significant still are such fossil forms as *Plesiochelys solodurensis* Rüttimeyer, and *Platychelys oberndorferi* Wagner, from the Upper Jura, with carapaces showing essentially the same plan of scutes and plates as is found in turtles of to-day, except that the dovetailing of neural and costal scutes is less noticeable. I should be slow to draw inferences from the variations in modern turtles regarding the types of periods more remote than the Upper Jura.

Finally, in the abnormalities we have to do not merely with *supernumerary scutes* but with many instances of turtles with less than the typical number of elements, which cases it would be difficult to explain primarily by reversion. If turtles may have *less* than the typical number (even to only *three scutes in each* dorsal series, in No. 35), otherwise than by reversion, why may not they have *more* in the same way?

SUMMARY OF PART III.

1. The experiments in incubation are suggestive of the possible significance of external conditions in the causing of abnormalities of scutes.

2. I can attribute to supernumerary scutes no value for deductions as to the phylogeny of turtles.

3. Whether or not atavism may have a remote or indirect connection with the abnormalities (for which I see no evidence) I do not regard individual scutes as atavisms.

4. Many of the abnormalities are clearly *not* atavisms.

Note.

As my conclusions in regard to the significance of abnormality of scutes is in opposition to that with which Newmann starts out, and may, therefore, seem inimical to his hypothesis, I think it proper to state that the value of Newmann's view of the evolutionary history of the carapace appears to me to be largely independent of the question of atavism since the more essential features were really based on comparative anatomy, not systematic atavism. He supposes fourteen primitive series of scutes; of the five not present in most turtles, only one was found in his *abnormalities* (interplastrals), while three were represented by *normal* series of certain species (interplastral and supramarginals, two) and another only by *normal* scutes of the tail of Chelydra. My observations might, it is true, show in abnormality representatives of the supramarginal series, but, just as well, they would give reason to infer primitive division of neurals and the primitive presence of a pair of *submarginal* series, neither of which inferences would be in harmony with his view. Hence the

number of series involved in his view seeks its basis, not in supposed atavisms, but in comparative normal anatomy.

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EXPLANATION OF PLATES.

Figs. 1-13, plates I-VI, photographs of shells of diamond-back terrapin.

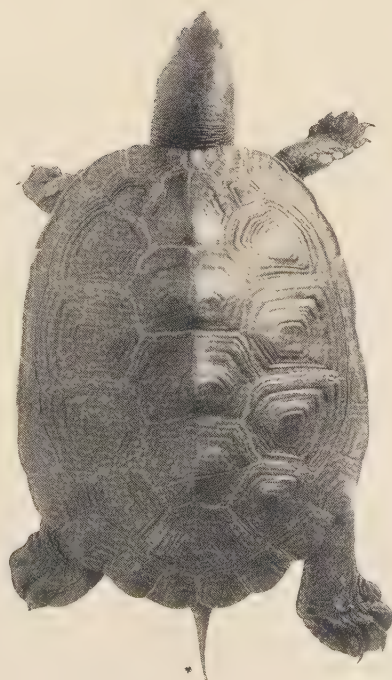
Figs. 14-54, plates VII-XI, sketches of plan of scutes of diamond-back terrapin; when only a portion of the carapace is shown, the drawing is from a field-sketch; Fig. 51 omitted; Figs. 53 and 54 from terrapin of Texas (see p. 31).

Figs. 55-104, plates XI-XIV, drawings of plan of scutes of embryos and new-born of the loggerhead sea-turtle.

In the first eleven plates the figures in parentheses following the number of the illustration refer to the serial number of the specimen in tables I-V; in the succeeding plates (and in plate XI if preceded by the letter "T") the numbers refer to the specimens of *Thalassochelys* of tables VI-IX.



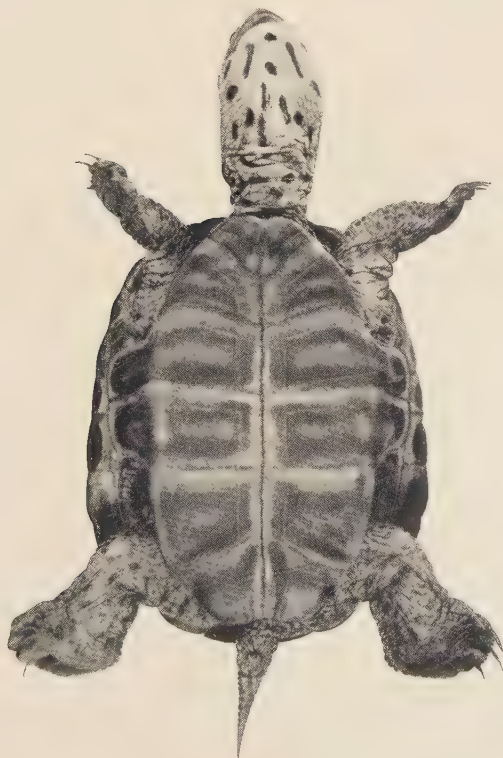
1 (70)



2 (244)



3 (9)



4 (9)



5 (210)



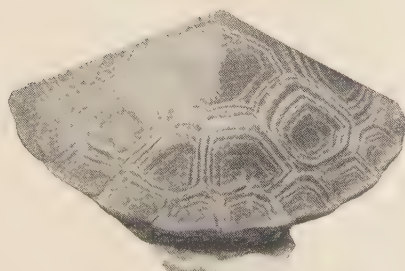
8 (195)



6 (150)



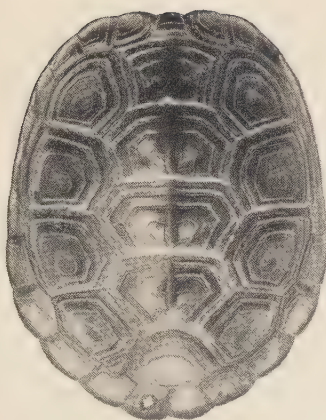
7 (151)



11 (149)



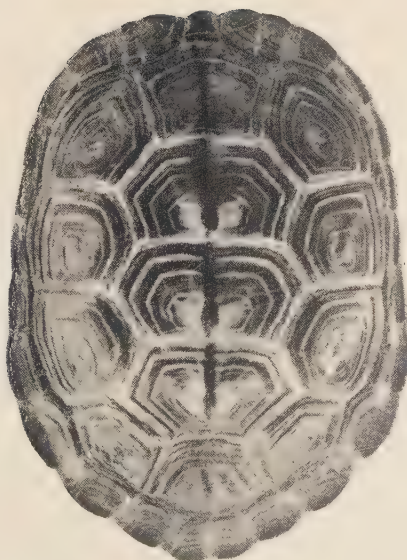
9 (131)



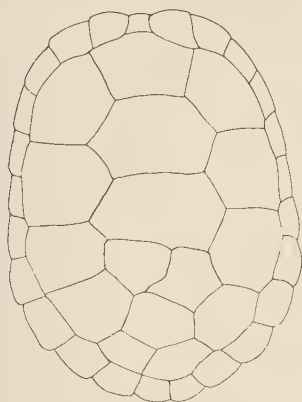
10 (133)



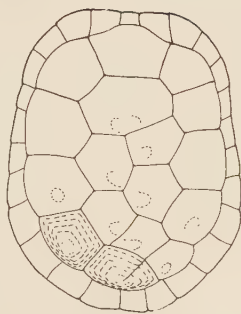
12 (88)



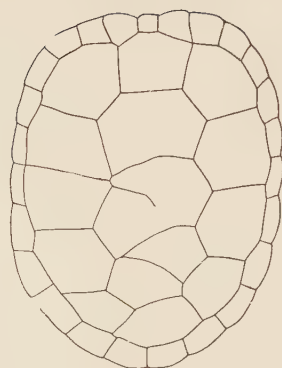
13 (126)



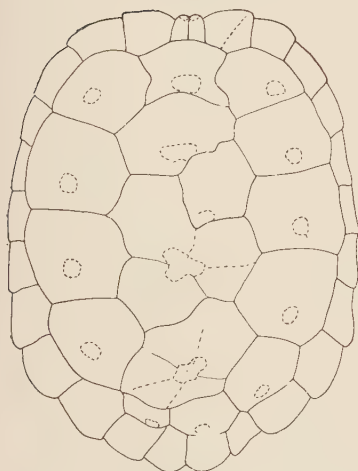
14 (251)



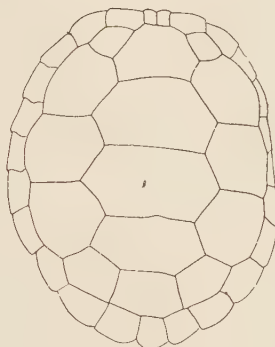
15 (151)



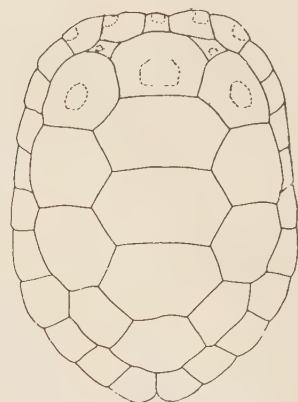
16 (167)



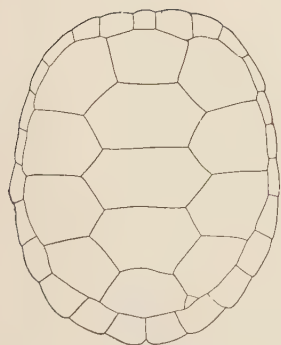
17 (210)



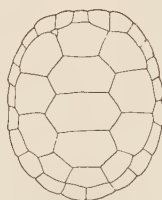
18 (245)



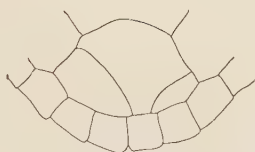
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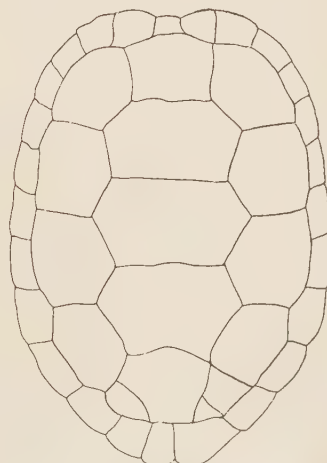
21 (56)



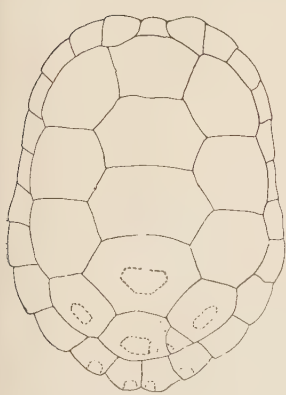
20 (4)



22 (228)



23 (256)



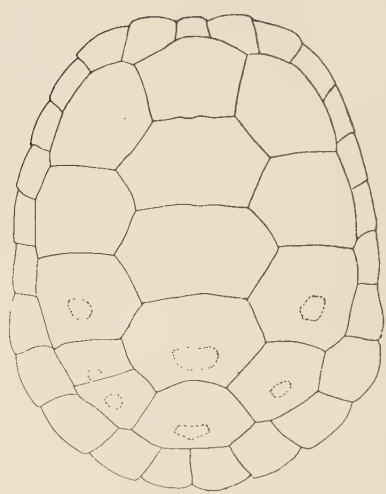
24 (247)



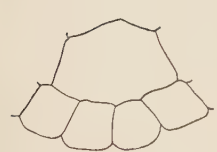
25 (223)



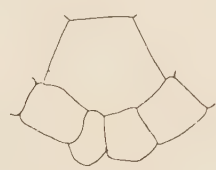
26 (174)



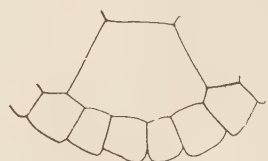
27 (257)



28 (191)



29 (185)



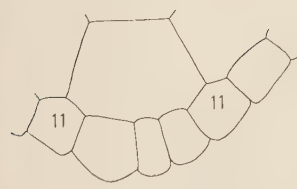
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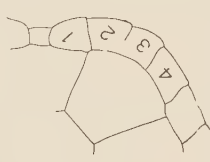
32 (209)



31 (196)



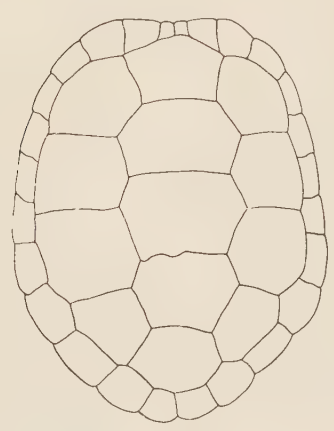
33 (183)



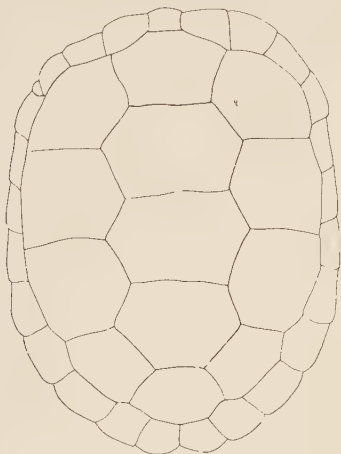
34 (176)



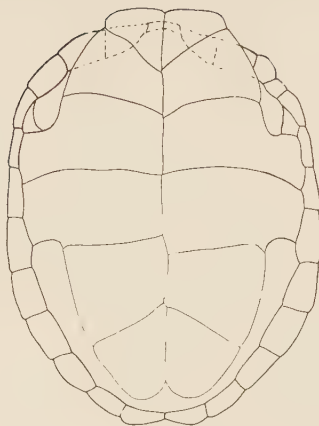
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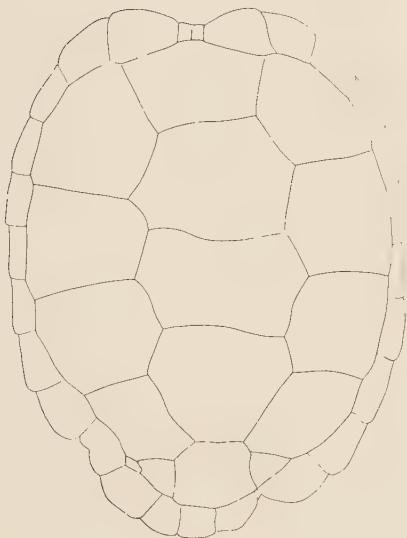
36 (249)



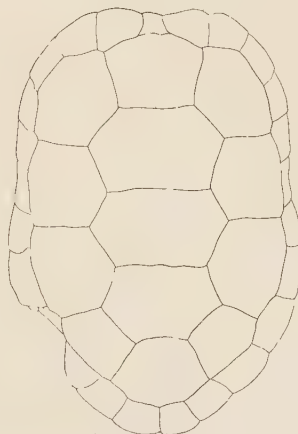
37 (145)



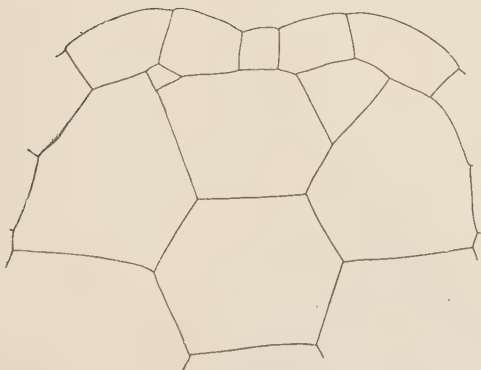
38 (145)



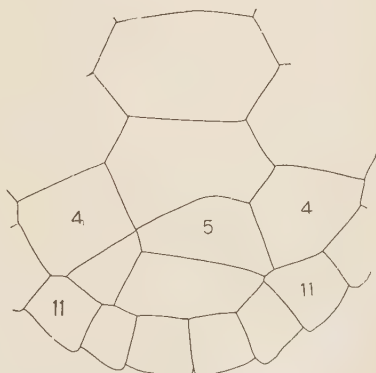
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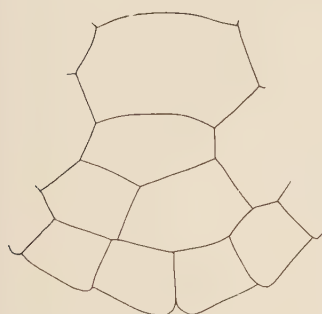
40 (248)



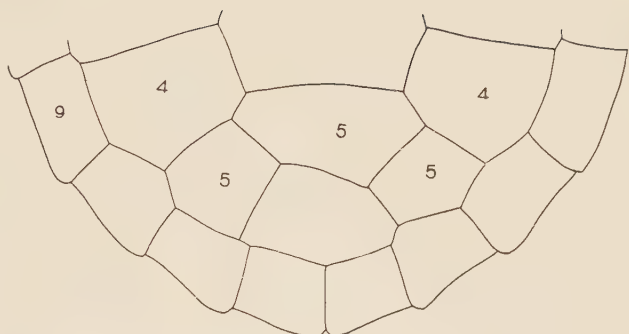
41 (218)



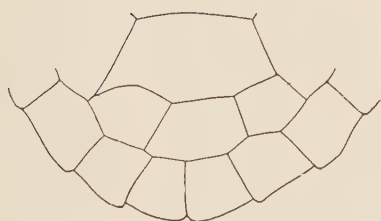
42 (196)



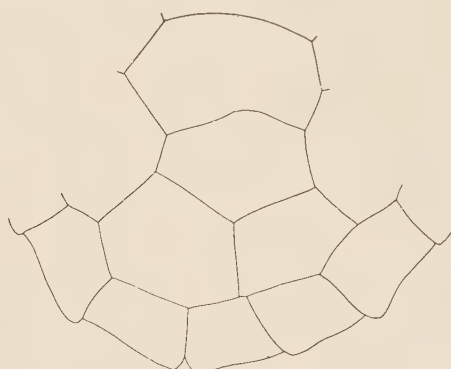
43 (199)



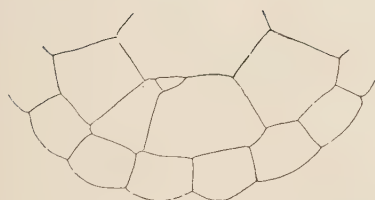
44 (218)



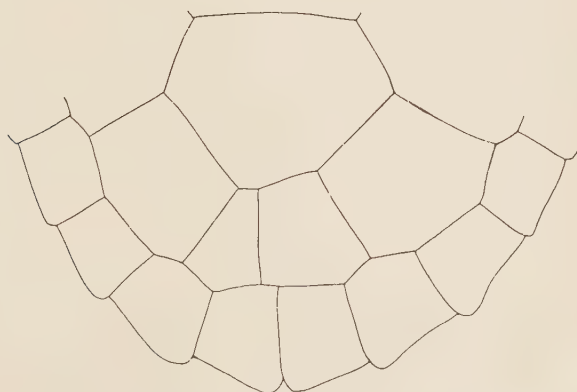
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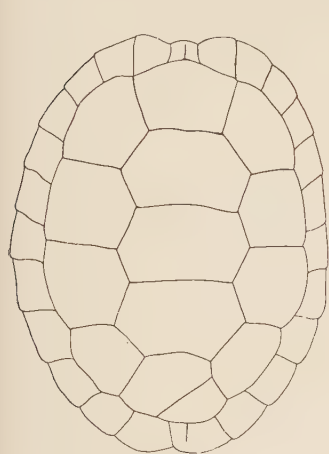
46 (217)



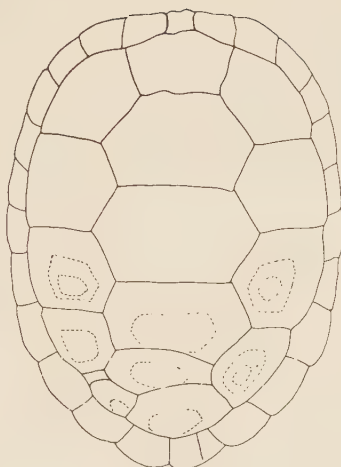
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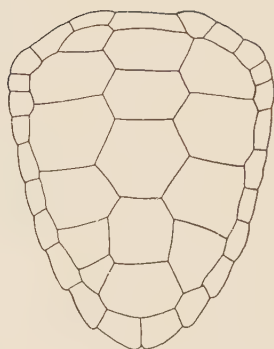
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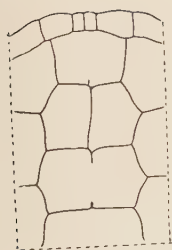
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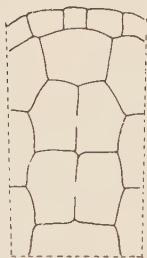
50 (250)



52 (T 10)



53 (259)



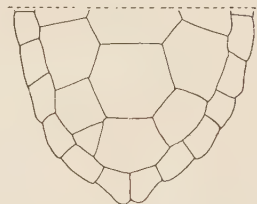
54 (260)



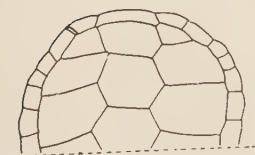
55 (T 17)



57 (T 6)



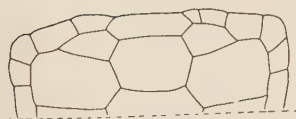
56 (T 14)



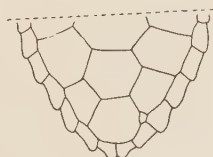
58 (T 15)



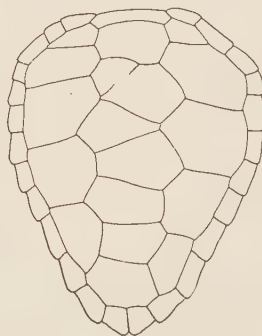
61 (T 23)



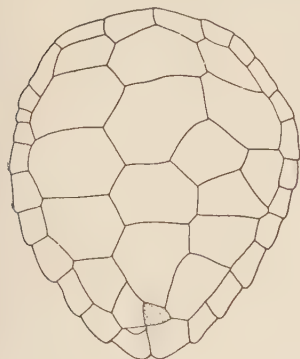
59 (T 19)



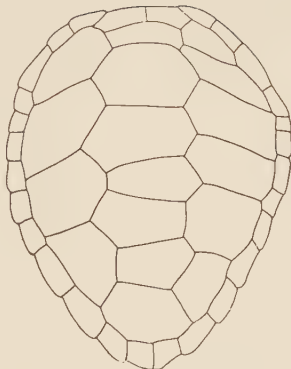
60 (T 25)



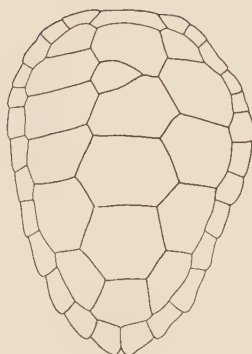
62 (T 24)



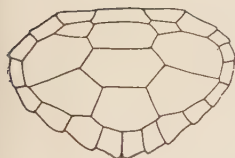
63 (26)



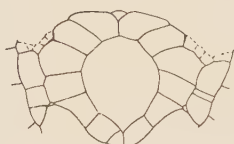
64 (30)



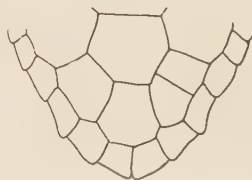
65 (31)



66 (35)



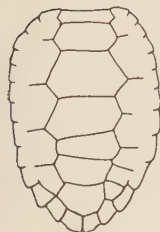
67 (35)



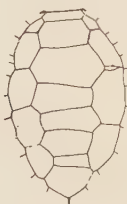
68 (66)



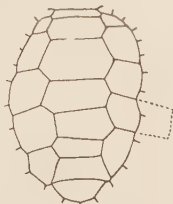
69 (42)



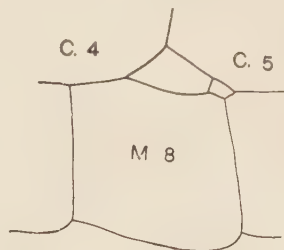
70 (45)



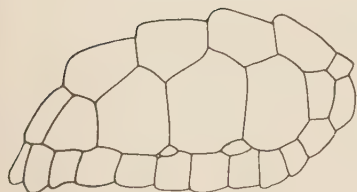
71 (37)



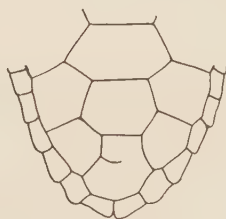
72 (43)



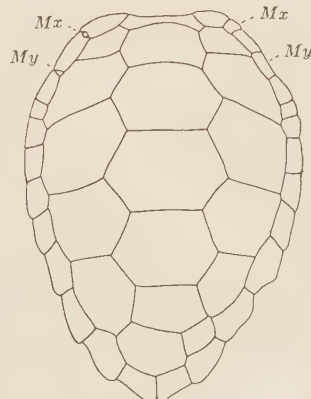
73 (48)



74 (48)

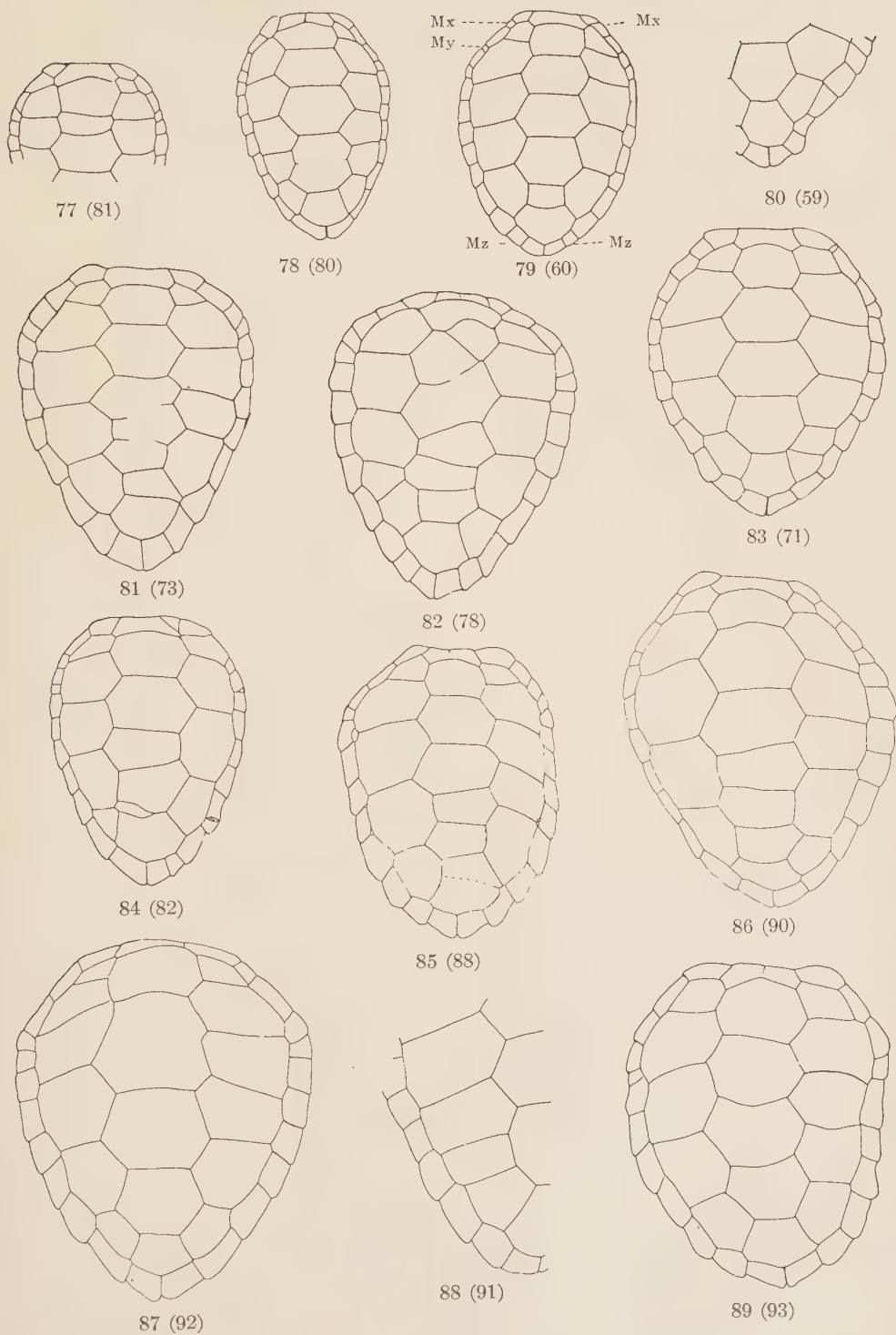


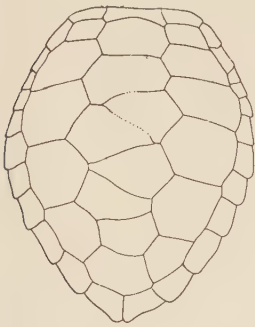
75 (54)



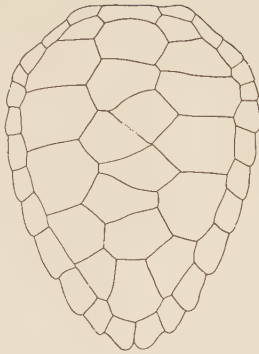
76 (69)

ROBERT E. COKER.

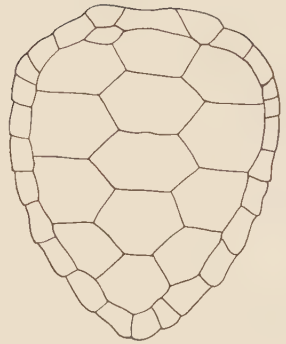




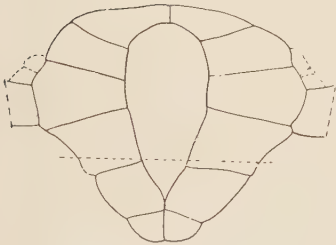
90 (94)



91 (97)



92 (98)



93 (100)



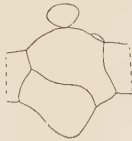
94 (102)



96 (103)



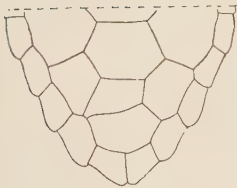
97 (107)



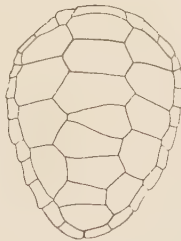
95 (100)



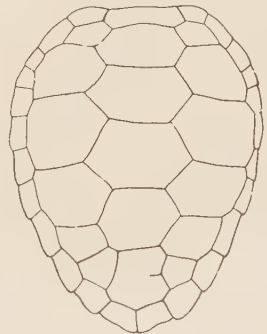
98 (104)



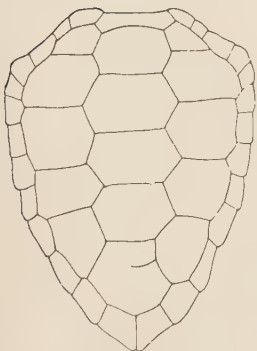
99 (109)



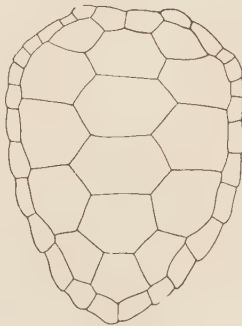
100 (209)



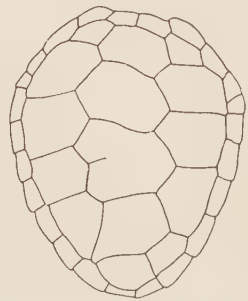
101 (114)



102 (120)



103 (112)



104 (210)

BIOGRAPHY.

Robert Ervin Coker, son of William C. and Mary McIver, was born at Society Hill, South Carolina, June 4, 1876. He received a common school education in Darlington, S. C., and entered the South Carolina College in 1892; after one year he removed to the University of North Carolina, from which institution he graduated in 1896 with the degree B.S.; the degree M.S. was received in 1897; during the years 1895-97 he served as Assistant in Biology. He taught private school one year, and was Principal of Goldsboro (N. C.) Public Schools from 1898 to 1901; in the summers, served as instructor in the University of North Carolina Summer School and as investigating assistant in the United States Fish Commission Laboratory at Beaufort, N. C. He entered the Johns Hopkins University in 1901; was Biologist of the North Carolina Geological Survey and Custodian of the United States Fisheries Laboratory at Beaufort, 1902-1904; returned to this University in 1904, and was appointed Fellow in 1905.

